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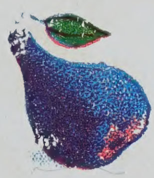

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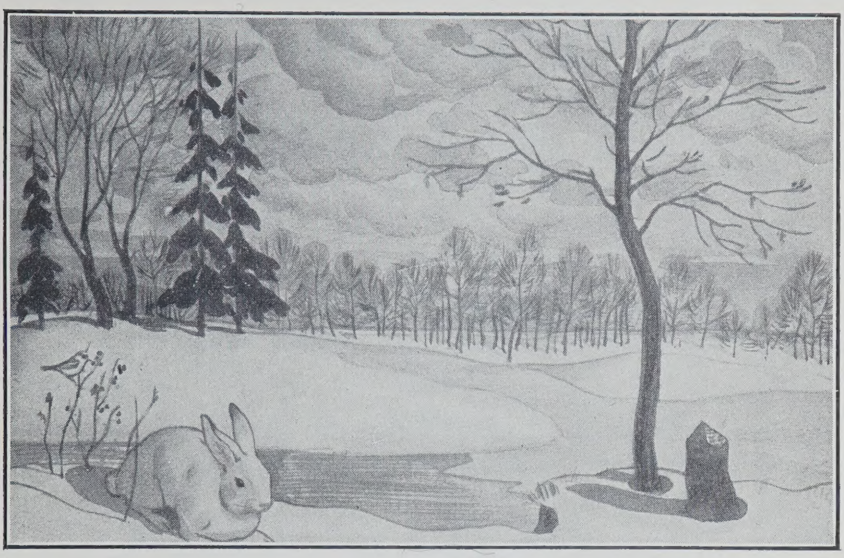
BY THE SIDE OF THE BROOK IN SUMMER

There are interesting stories written in every field and woodland for all who have learned to read them. The "Story of Summer and Winter" told in these pictures is one of the many that we may all learn to understand and enjoy by observing nature indoors and out.

Under the rays of the summer sun the plants, the animals, and the brook itself are full of life. The leaves are rustling in the gentle summer breeze; the flowers are holding up their faces to the sunlight; the brook is singing as it runs down to the sea; and the birds and other animals are revelling in the sunshine while they leisurely eat of the store of food so bountifully spread for them by nature.



BY THE SIDE OF THE BROOK IN WINTER

But when the slanting rays of the winter sun bring only scanty warmth, what a great change comes over the scene! The trees, shrubs, and other plants are all prepared for winter. The grasses are protected by a blanket of snow. The rabbit alone, of all the animals, is braving the chilling winds of winter.

What has become of the summer birds? What is the food of those that remain? Where are the frog and the snake? How are the squirrel and the bear spending the winter? Why is the rabbit safer in his new white coat? Are the inhabitants of the brook protected by the covering of ice? What would become of them if ice were not lighter than water?

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SCIENCE INDOORS AND OUT

BOOKS I AND II

BY

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AUTHORIZED BY THE ADVISORY BOARD OF THE DEPARTMENT OF EDUCATION FOR USE IN THE SCHOOLS OF MANITOBA

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THE EDUCATIONAL BOOK CO., LIMITED
1931

485 pp

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PREFACE

It is very natural for boys and girls to wonder about the things around them and about the phenomena of nature. They ask many questions. If they find answers, their interest is stimulated, and new questions arise in their minds. These new questions call forth renewed effort and develop their enthusiasm. If, however, they are unable to find answers, they quickly become discouraged by failure and cease to think of new questions. Their minds become occupied with the commonplaces of everyday life that call forth little real thought.

While the minds of pupils are still eager to discover new things, the time is opportune to offer them a course in science that is designed to develop in them the ability to find answers to their own questions. The aim of this book is therefore to bring before the pupils many things from nature in which they are interested, and to guide them in finding answers to the questions which these things suggest.

In the organization of the work the authors have kept in mind the fact that they are dealing with beginners in science, and that to expect too much of them is only to invite failure. Where a trained mind would grasp the whole significance of an observation, a beginner must be given any points that he may have missed. Furthermore, the confidence of the beginner must be repeatedly strengthened by finding that what he has already thought out, or partly thought out, for himself is actually true.

Each chapter of the work is laid out definitely around particular specimens that the pupils can handle, or around experiments that they are able to perform. Details of

procedure are set forth clearly and simply in language suited to the pupils. This permits the teacher to spend the greater part of the lesson period in supervision of the practical work of individual pupils.

The specimens and apparatus called for are in every case simple and easily obtained. Without these simple essentials, however, no lesson can be a success. It is therefore assumed throughout the work that proper specimens and apparatus are in every case available when required. In classrooms where more than one grade is being taught, and much seat work must be given, pupils provided with the necessary specimens and equipment can, with the aid of the text, continue to work by themselves.

Options are essential in a practical science course such as this, which is planned to meet the needs of schools located in regions varying from the open prairie to the wooded north, and differing as widely as one-roomed rural schools differ from the specialized schools of the cities. Material is therefore included to meet this need. This inevitably enlarges the book, but it does not lengthen the course, since no class will be required to cover all the options.

As aids to the teacher in organizing the work of the classes, definite teaching projects, question outlines, and reviews are provided. Regarding the preparation and manipulation of materials and equipment, many practical suggestions which have been found serviceable in the classroom are included in the Appendix.

Nearly all of the large number of diagrams and other illustrations have been specially prepared for this book. The care exercised in planning and preparing each diagram will, it is believed, result in particularly clear presentation to the pupils of the points to be emphasized. Great credit is due to the artist, Mr. John Jones, of St. John's Technical High School, Winnipeg, for his untiring efforts to secure the

exact effects required. For the cover design the authors are indebted to Mr. H. Valentine Fanshaw, Art Director of Kelvin Technical High School, Winnipeg. Photographs loaned by naturalists, by government departments, and by publishers and other commercial organizations are acknowledged where they appear.

For continuous and unfailing practical assistance in the effort to adapt new materials to the new needs of the schools, and for the inspiration to develop the material of classroom lessons into book form, the authors wish to acknowledge their indebtedness to Mr. J. C. Pincock, Assistant Superintendent of Schools, Winnipeg. For the aid given and helpful suggestions made by many experienced teachers using the material in their classrooms the authors wish to express their thanks. Further suggestions calculated to make the book more serviceable to teachers and to pupils will be welcomed.

Winnipeg, September, 1929.

C.A.E.H.
D.A.P.

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BOOK ONE

PART I. AUTUMN STUDIES OF PLANT LIFE

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SUGGESTIONS TO TEACHERS REGARDING SEASONAL ARRANGEMENT OF TOPICS

In a course so closely linked with the seasonal changes out-of-doors much latitude must be allowed in the arrangement of topics.

Alternating courses.—The organization of the work is such that the order of topics may be varied. Where it is advantageous to teach Grades VII and VIII together, the topics of Book One and Book Two may be arranged to form two courses to be taken in alternate years by both grades working together.

Other variations in the order of topics.—The fall work on insects should be covered while living specimens are available. It may be advisable, therefore, where the weekly allotment of time is inadequate, to insert Chapters VIII to XI (Insects) between Chapters V and VI. This may be done without undue interruption. Other changes in the order of work may be found to increase the effectiveness of the course in particular cases, and teachers should feel free to make such alterations where need arises.

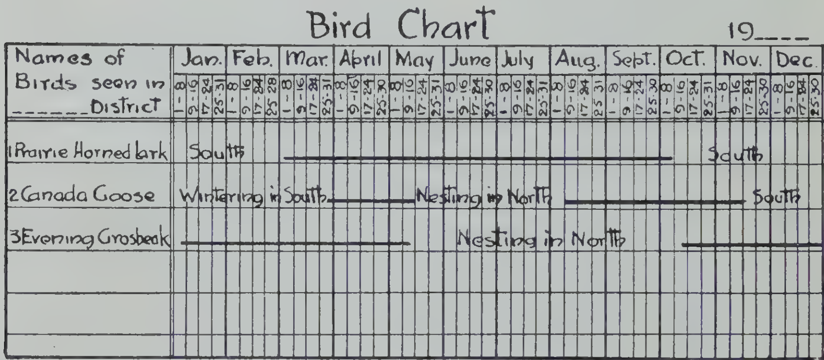
Provision of specimens and apparatus.—Specimens and apparatus should be collected or ordered from dealers well in advance of the time when they will be required.[1] All specimens and apparatus required for the work of each chapter are indicated under *Teaching Projects*. The specimens called for are, in nearly every case, abundant at the time when they are required. In cases where they are available earlier, the work may be re-arranged to suit the

[1] Obtain catalogues from dealers in apparatus and supplies, including charts and specimens. Do not omit mounting materials required for Chapter XXVI or for Appendix, Sec. 20.

season, or specimens may be collected and preserved. Care should be exercised in arranging for specimens so that full advantage may be taken of the options offered in the *Programme of Studies*. Chapter IX, *The Bee*, and Chapter X, *The Grasshopper*, for example, are written as alternatives; therefore specimens need not be provided for both.

Records of changes in the sun's position.—In order that observations of changes in the sun's position may be made over a sufficient length of time to give results, it will be necessary to commence making records in September. (See Appendix, Sec. 1, and Chapter XIII.)

Records of the residence and migration of birds.—Records of the residence and migration dates of birds should be kept throughout the year on a classroom chart such as the following:



Grasses.—In order that plants of wheat, oats, barley, and rye may be available for the study of the grass family, they should be obtained before the crops are all cut. One or two complete plants of each kind should be mounted in glass or celluloid tubes as suggested in the Appendix (Sec. 15). Heads of such grasses as timothy, brome grass, couch grass, rye grass, wheat, oats, and barley will not likely be found in the autumn with fresh stamens on them. A few

specimens showing stamens should therefore be collected during the early part of the summer, preserved in liquid,[1] and placed in the school collection.

Corn.—Tassels of corn showing fresh stamens, and ears of corn partly developed, should be collected early in the season or as soon as school opens. They should be preserved in liquid. Of the tassels only single branches need be preserved. These should be placed in separate test-tubes so that they may be easily seen.

The sunflower family.—The study of the sunflower family should be made while fresh specimens are available. To allow for this, the work of *mounting* pressed plants (Chapter XXVI) may be postponed, the plants being left in the press until required.

Rodents.—Outdoor observations upon living rodents should be made gradually from the beginning of the term, and specimens such as rabbits, white rats, or guinea pigs should be available for close study later.

If living animals are brought in, they should be kept in a clean, comfortable cage (see Appendix, Secs. 16-18) for the pupils to observe even if they are not studying the section dealing with rodents at the time. If dead specimens are brought in, the heads may be stored in 10 per cent formalin until the skulls can be cleaned. Rabbit skulls are very satisfactory, but skulls of gophers, rats, mice, and other rodents add greatly to the usefulness of the collection for teaching purposes.

For methods of cleaning and mounting skulls see Appendix (Secs. 21-22). Pupils learn a great deal from doing this practical work, and credit should be allowed for it.

Record of box elder (Manitoba maple).—To assist in the spring studies of the flowers of the Manitoba maple

[1] A 3 per cent solution of formalin is sufficient to preserve them, but in schools where freezing is likely to occur a 75 per cent solution of methyl hydrate should be used. Glycerine-alcohol anti-freeze may be substituted.

trees, the location of one maple tree bearing seeds ("keys") and one without seeds should be accurately recorded by each pupil in a note-book. Small trees should not be marked because they may be too young to produce flowers or seeds. If the trees chosen for record are passed daily on the way to school, it will be possible to observe their flowers as they develop in the spring. One tree of each kind located in the school grounds may be marked as well for class observation in the spring.

The following examples show how the location of a tree may be recorded in the note-book. "Tree No. 5 east from S. E. corner at Pine and Ash Streets." "Tree nearest the front gate of 125 Elm Street." "Tree nearest the N. E. corner of the barn." A sketch map to show the location is helpful.

If the trees selected for study are located in a bluff, it may be necessary to tie a luggage, cardboard, or wooden label loosely around one branch of each tree. (A tight cord on a limb would injure it.)

Frogs.—Work on the frog should be taken up at a time when the eggs can be secured. They will be found after the singing of the frogs has become quite general in the spring.

Snakes.—As snakes can be easily preserved in strong formalin or methyl hydrate, one or more should be placed in the school collection as soon as located. They may be coiled in a sealer or placed in a long straight tube large enough to contain them. A living garter snake or other harmless kind should be kept in a cage for observation.

TEACHING PROJECTS, SPECIMENS, AND REFERENCES

Book One

PART I. AUTUMN STUDIES OF PLANT LIFE

Chapter I. Making a Good Beginning.—(Page 1).

Teaching Projects.—The chief aim in this introductory work is to emphasize the value of careful planning and careful recording of our work. The lists of "Uses of Plants to People" require both plan and record, but deal with very familiar material. They also emphasize the need of proper equipment from the beginning, and give opportunity for setting a high standard of work for each member of the class.

Chapter II. The Parts of a Simple Flower and Their Uses.—(Page 5).

Teaching Projects.—To show by examining a simple regular flower the following points: (1) The flower and its function, color, perfume, nectar (and pollen)—attraction of insects. The insect visitors and what they do. (2) The parts and their uses: calyx (sepals), corolla (petals), stamens (anther with pollen, filament), and pistil (stigma, style, ovary). (3) The development of the pistil to a seed pod.

Specimens.—Nasturtium flower. One fresh flower and one with withered corolla and enlarged pistil for each pupil. Any other simple regular flower may be substituted in which the four circles—calyx, corolla, stamens, and pistil—are all easily seen *without removing any parts*. The impression that studying a flower means "pulling it to bits" should be avoided in this first study.

Chapter III. How the Pea Flower Makes a Seed Pod and Seeds.—(Page 13).

Teaching Projects.—The study of specimens of the pea flower to show that an irregular flower has the same parts and functions as a simple flower but gains additional advantage by its peculiar form. (1) The recognition of the parts of an irregular flower. (2) How the irregularity of this flower favors cross pollination by an insect of the bee type. (3) The development of the pistil to a seed pod with seeds.

Specimens.—(1) Fresh flowers of sweet pea or other large flowers of the same family. (2) Old withered flowers of the same kind showing pistils developing into seed pods, one specimen for each pupil in each case.

Chapter IV. Making and Arranging a Collection of Seeds and Fruits.—(Page 16).

Teaching Projects.—The collection, mounting, and study of specimens of seeds and fruits showing: (1) The application of the term "fruit" to all seed vessels. (2) The need for a wide dispersal of seeds. (3) The classification of fruits and seeds according to the agents of dispersal. (4) Typical examples showing special adaptations for dispersal by various agents.

Specimens.—Seed vessels of all kinds that can be found, dry and fleshy, and mounting materials as indicated.

Chapter V. How One Seed Produces Many New Seeds.—(Page 24).

Teaching Projects.—(1) From a specimen wheat plant, to explain the origin of the world's bread supply in the natural increase of grains. (2) From a specimen of wild plant to show how, even with a wide "margin of safety" of seed production, there is little, if any, increase following the chance dispersal by wind, water, and other agents.

Specimens.—A full-grown wheat plant pulled up by the root. Peppergrass or a similar annual with many pods (see page 27). One plant per twelve pupils is sufficient.

Chapter VI. How Plants Prepare for the Hardships of Winter.—(Page 29).

Teaching Projects.—From outdoor observation and from specimens to see: (1) The need for special methods of protection during the winter season. (2) The methods used by evergreens and winter annuals: slight external change, thickening sap. (3) The methods of deciduous trees: shedding their leaves, sealing their stems with cork.

Specimens.—(1) A twig of spruce or other evergreen with needle leaves. (2) An autumn rosette of Frenchweed or a similar plant (page 32). (3) A specimen of the same with pods. (4) A branch of maple or other tree (one for each pupil) showing twigs and buds with leaf scars.

Chapter VII. How Plants Prepare for the Hardships of Winter (Continued).—(Page 37).

Teaching Projects.—To see from out-door observation and from specimens: (1) The preparation of herbaceous perennials and biennials that dispense with stems as well as leaves. (2) The preparation of annuals that die completely but leave new plants in their seeds.

Specimens.—(1) Dig up an herbaceous perennial (e.g., sow-thistle) in winter condition, showing the stem and leaves withered but the root undamaged. (2) A carrot or other biennial fleshy root. (3) Any annual (e.g., poppy) dead after ripening its seed.

PART II. AUTUMN STUDIES OF ANIMAL LIFE

Chapter VIII. Insect Friends and Enemies.—(Page 45).

Teaching Projects.—(1) To make outdoor observations and use those previously made showing how some flying insects render service to flowers and how others are excluded. (2) To observe insects harmful to plants and to collect specimens of their work. (3) To explain the harm done by some insects to people and animals. (4) To illustrate the usefulness of some insects: (*a*) the bee, (*b*) the silk-worm, (*c*) parasites and predaceous insects preying upon harmful kinds.

Specimens.—(1) Living specimens of caterpillars, aphids, potato beetles, wood-boring insects, or other harmful kinds. Keep these in cages with food plants. (2) Specimens to be preserved in test-tubes for future reference. (3) Galls of any available kind. (4) A caterpillar with parasites (Fig. 56). (5) A bee, a lady beetle, and other useful insects. Silk cocoons and others.

References.—(1) *Grasshopper Land* by Margaret Morley. Chicago: A. C. McClurg & Co. (2) Bulletins on insects, which may be procured from the Publications Branch, Department of Agriculture, Winnipeg.

Chapter IX. The Honey-bee.—(Page 54).

Teaching Projects.—(1) Using the bee as a specimen, to see the body parts of a typical insect: head, thorax, and abdomen, with the parts attached to each and the uses of these parts. (2) To show the special features of body structure and of life history by which the bee is adapted for partnership with flowers, and for collecting and protecting its store of winter food. (3) To give an understanding of the division of labor among the bees and an appreciation of the effective service rendered by each member in the interests of the whole colony.

Specimens.—(1) Living bees in fruit-jar cages (one per two pupils, see page 70). (2) Worker bees, preserved, one for each pupil. (3) A honeycomb, full or empty. (4) Specimens of queen, drone, and worker bees (preserved or fresh). (5) A brood comb with pupa and other stages.

References.—(1) *The Honey-Makers* by Margaret Morley. Chicago: A. C. McClurg & Co. (2) Reports showing the value of wheat, fruit, and honey, which may be procured from the Publications Branch, Department of Agriculture, Ottawa, or Winnipeg. (3) *Nature Study and Life* by C. F. Hodge. Boston: Ginn & Co.

Chapter X. The Grasshopper.—(Page 70).

Teaching Projects.—(1) Using the grasshopper as a specimen, to make familiar: (*a*) the body parts of insects and the uses of the parts, (*b*) the three-stage life history of this group of insects. (2) To show the special structures of this insect by which it is adapted to its particular abode, and its method of living. (3) To give an understanding of the economic importance of grasshoppers as a result of the damage they cause, and of methods of control.

Specimens.—(1) Living specimens of grasshoppers in cages (Fig. 69), one per two pupils. (2) Preserved specimens of grasshoppers, one per pupil. (3) Look for grasshoppers showing parasites. Preserve these.

References.—(1) *Grasshopper Land* by Margaret Morley. Chicago: A. C. McClurg & Co. (2) Bulletin on *Poisoning Grasshoppers* and other bulletins on insect pests. Winnipeg: Publications Branch, Department of Agriculture. (3) Bulletins on insects harmful to plants, animals, and people. Ottawa: Publications Branch, Department of Agriculture.

Chapter XI. The Cabbage Butterfly and Other Harmful Insects. —(Page 82).

Teaching Projects.—(1) Using the cabbage butterfly as a specimen having a typical four-stage life-history, to show that the larva is the harmful stage in most biting insects. (2) To show that biting insects such as caterpillars may be destroyed by food poisons. (3) Using aphids as specimens, to show the sap-sucking method of feeding, and to explain how contact poisons may be used to destroy this type of insect enemy.

Specimens.—(1) Cabbage butterflies in cages (page 70) or mounted dry, one per two pupils. (2) Egg, larva, and pupa stages preserved or alive, one per six pupils. (3) Caterpillars in cages with cabbage, to feed until changed to pupa. (4) Other harmful insects as in Chapter VIII.

References.—Bulletins as in Chapter X above. Write to the Publications Branch, Department of Agriculture, at Ottawa and at Winnipeg, asking for the latest *List of Publications.*

Chapter XII. Our Friends the Birds.—(Page 90).

Teaching Projects.—(1) Using bird specimens, bird pictures, and outdoor observations, to give some exact information as to the external structure of the bird's body and the uses of its parts, including colors and moulting of feathers. (2) Using this information, to derive a simple classification of common birds into groups according to habitat and food habits. To develop from this classification some ability to identify birds with the help of descriptive books. (3) From observation of their food

habits, to give an understanding of the economic value of birds and of the necessity of northward and southward migration. (4) From acquaintance with the interesting structure, the life activities, and the economic value of birds, to develop an enthusiasm for the protection and encouragement of birds about our homes.

Specimens.—(1) A large mounted bird (or living bird), a collection to be built up. (2) Wings of birds, spread and mounted (see Appendix, Sec. 7), one per two pupils. (3) Feathers, three types (see page 92), one each per pupil. (4) Colored pictures of the same bird as the mounted specimen, these mounted under glass (see Appendix, Sec. 6), one per pupil. (5) Bird outlines (see footnote page 103).

References.—(1) *Birds of Western Canada* by P. A. Taverner. Ottawa: Publications Branch, Department of Agriculture. (2) *Game Laws and Regulations*. Winnipeg: Game Branch, Department of Agriculture. (3) Crow competition leaflets.

PART III. STUDY OF TEMPERATURE CHANGES AFFECTING PLANT AND ANIMAL LIFE

CHAPTER XIII. TEMPERATURE AND ITS MEASUREMENT.—(Page 111).

Teaching Projects.—(1) To make a summary of the changes in plant and animal life as weather temperatures lower. (2) To show by experiments: (*a*) what temperature is, (*b*) how to make a large model of a thermometer and learn what the two thermometer scales mean and how to read them, (*c*) why pure water can be used to find freezing and boiling points, (*d*) the effect of changes in temperature on iron, air, and water, in order to explain the principle upon which thermometers are based.

CHAPTER XIV. WATER TO ICE.—(Page 127).

Teaching Projects.—(1) To show by an experiment the changes in volume that take place when water cools down and freezes. (2) To emphasize the vital importance in nature of the fact that water expands when it freezes or solidifies.

CHAPTER XV. FORMATION OF CRYSTALS.—(Page 133).

Teaching Projects.—(1) Experiments to show that some substances, on changing from a liquid to a solid, assume definite shapes forming crystals. (2) To indicate that ice and snow and frost patterns are crystalline forms of water.

Chapter XVI. Ice to Water.—(Page 138).

Teaching Project. — To show by experiments: (*a*) the changes in volume that take place when ice changes back to water and heats up, (*b*) that the freezing and melting points of water are the same, (*c*) the effect of ice on the temperature of water in which ice is melting, (*d*) that other substances besides water change their state but at different temperatures.

Chapter XVII. Evaporation.—(Page 144).

Teaching Projects.—(1) To show the effect of temperature on the evaporation of water into the air. (2) To show that evaporation takes place under widely varied conditions of temperature.

Chapter XVIII. Recovery of Water Vapor From the Air.—(Page 148).

Teaching Projects.—(1) To show how water vapor may be recovered from the air and to demonstrate how dew is formed. (2) To explain the formation of mist and clouds and show the importance of rainfall and snowfall.

Chapter XIX. Great Movements of Water.—(Page 155).

Teaching Projects.—(1) To show that water moves in a cycle, (*a*) falling as snow and rain, (*b*) then quickly evaporating again, running off, or sinking into the ground, and (*c*) finally evaporating back into the air. (2) To show the importance to us of (*a*) run-off water, (*b*) water that sinks into the ground.

Chapter XX. Water as a Solvent.—(Page 166).

Teaching Projects.—(1) To show by experiment that all natural waters contain dissolved materials and that the amount increases as water flows over or through the soil. (2) To show why we call some waters "hard" and others "soft"; and to show how to soften hard water. (3) To stress the importance and use of water as a solvent. (4) To show that not all substances are equally soluble, and the importance of this.

Chapter XXI. Purification of Water.—(Page 175).

Teaching Projects.—(1) To purify a sample of water by distilling it. (2) To indicate how water in the country as well as in the city may be made safe for drinking.

CHAPTER XXII. FACTORS AFFECTING SPRING TEMPERATURES.—(Page 180).

Teaching Projects.—(1) To show why we experience low temperatures during the winter. (2) To show that the sun has not the same heating effect on a white as on a black object. (3) To show the effect of snow upon temperature. (4) To demonstrate how some materials are better conductors of heat than others. Some practical applications. (5) To explain how heat is conducted. (6) The earth's crust and water are poor conductors of heat. The effect of this on temperature. (7) To show how to keep our houses and our bodies warm or cool. (8) To show how heat from the sun or from a bonfire reaches us. (9) To show which surfaces radiate heat better. Apply this to the effect of white snow on temperature. (10) To see how the sun is our great source of heat.

PART IV. SPRING STUDIES OF PLANT AND ANIMAL LIFE

CHAPTER XXIII. SEEDS AND GERMINATION.—(Page 203).

Teaching Projects. — This topic offers special opportunities. In it the material is almost ideal for the development of abilities of observation and organization. With this material each pupil may be led to the accomplishment of a piece of individual scientific work. (1) To examine specimens of large seeds and grains to find their external parts and show the uses of the same. (2) To find the young plant inside the seed and observe the store of food provided for it, noticing the difference between seed and grain in this respect and in the number of cotyledons. (3) To germinate seeds and grains observing their growth to the completion of germination and comparing the development of different types. (4) To find the conditions necessary for germination: water, air, heat. (5) To show how seeds are disinfected to destroy disease germs and how they are tested to find what proportion of them will grow.

NOTE.—In order to have sprouted seeds ready for the class to examine while waiting for their planted seeds to germinate, the germinator (see page 211 and Appendix, Sec. 9) should be started when the chapter is begun and the sprouted seeds preserved in formalin as they reach the desired stage showing the first root branches.

Specimens.—Seeds of the wax bean, or the broad Windsor bean, the garden pea (any large smooth variety), and grains of corn (large flat variety) are required for the study of the parts of seeds. Six seeds of each kind should be provided for each pupil. This provides a few extras to allow for spoiled specimens. Three dozen extra pea seeds are required for the additional experiment. The seeds required for each pupil are as follows:

	Bean	Pea	Sun-flower	Corn	Others
I. Study of External Parts.........	2[1]	2[1]			
II. Study of Internal Parts	1	1			
III. Comparison of Grain of Corn ...				2	
IV. (1) Germination in Tumblers[2]...	2	2	2	2	2
(2) Observing Sprouted Seeds[2]....	1	1		1	

In addition to seeds of pea, bean, sunflower, and corn, there should be provided as extras two buckwheat, radish, or other seeds that germinate similarly to the bean. Different pupils may have different kinds. Four-ounce packages contain approximately the following numbers of seeds: peas, 300; golden wax beans, 225; corn, 400; sunflower, 1000.

For the germination experiment each pupil requires, besides the soaked seeds, the following: one clear glass tumbler, filled with bulb fibre, cocoanut fibre, sawdust, or other suitable material, a sheet of wrapping paper the size of his desk top, and two pieces of gummed paper tape as long as the tumbler. For details see Appendix, Sec. 8.

References.—(1) Circular 85, *Cereal Smuts*. Winnipeg: Publications Branch, Department of Agriculture. (2) Bulletin 73, *Smut Diseases*. Ottawa: Publications Branch, Department of Agriculture.

Chapter XXIV. Increase of Insects in the Spring.—(Page 217).

Teaching Projects.—(1) From observation of living specimens of insects, to review the life history, body structure, breathing and feeding habits of typical insects as studied in the autumn. (2) To become acquainted with the above details regarding the mosquito, potato beetle, or house-fly, and in each case to derive the method of control from the observations made.

Specimens.—Notice the options offered. See *Programme of Studies.* (1) Mosquito: living larvae in tumblers of pond water, one for each pupil. Cloth or wire screen covers for tumblers with elastic bands or string to fasten them on. A few drops of oil for each of the tumblers. (Larvae may be obtained already hatched in the ponds or by bringing in sods from land that was flooded for several weeks last spring and the previous spring. If these are covered with warm water, larvae will hatch from eggs on the grass or soil in an hour or two.) (2) Potato Beetle: Living specimens of larvae and adult beetles, one of each for each pupil. These may be kept in tumblers. Some should be kept for a week or more on a potato plant or on a raw potato in a cage. A preserved adult specimen should be available for each pupil also. (3) House-fly: Living specimens of house-flies may be caught in traps or on windows. They should be kept in a tumbler or test-tube for observation and should not be handled by pupils on account of the danger of infection. Some may be poisoned by providing them with a saucer of water to which has been added a teaspoonful of formalin and a little sugar or molasses. A fly poison that is not dangerous to people is made by dissolving one ounce of potassium bichromate in a

[1] One dry and one soaked. The soaked seeds may be kept in 5 per cent formalin.

[2] Notice carefully that these seeds must be alive, not soaked in formalin. They should be soaked in water before use. If soaked too long they will decay.

pint of water and exposing it in saucers. These poisons are most effective when the flies can obtain no other food or water. The poisoned flies should not be examined by pupils until after they have been disinfected by preserving them in 5 per cent formalin for some hours. Preserved specimens of eggs, larvae, and pupae should be available to pass around the class.

References.—(1) Mosquito: Report No. 17 National Research Council, *Mosquitoes. . . .and Their Control.* (This report describes the genus Aêdes, which is more common on the prairies than Culex, which lays its eggs in rafts, as shown in most text-books.) (2) Potato Beetle: (*a*) Bulletin, *Control of Potato Beetles and other Harmful Insects.* Winnipeg: Publications Branch, Department of Agriculture. (*b*) *Handbook of Nature Study* by Anna B. Comstock. New York: Doubleday, Page & Co. (3) House-fly: (*a*) Bulletin: *Control of House-fly.* Ottawa: Publications Branch, Department of Agriculture. (*b*) Booklets on *Fly Control and Directions for Making Fly Traps.* The Agricultural Extension Department, International Harvester Co., 606 So. Michigan Ave.. Chicago (price 15 cents). (*c*) *The House-fly* by G. Hewitt. Cambridge Science Series. Toronto: The Macmillan Co. of Canada, Ltd.

Book Two

PART I. AUTUMN STUDIES OF PLANT LIFE

Chapter XXV. Three Plants of the Mustard Family.—(Page 233).

Teaching Projects.—(1) From the study of specimens from this family to review the parts of a plant: root, stem, leaves, flowers, fruit, and seed, together with the uses of these parts. (2) To review the parts of a simple flower and their uses. (3) In this practical review to set up high standards of work and establish habits of thoughtful observation in the making of diagrams and in written exercises. (4) To observe in a group of three or more specimens the outstanding characters of the family, particularly those of the root, the flower, and the seed pod, noting the indeterminate habit of flowering and its consequences.

Specimens.—*First lesson.*—One whole plant of wild mustard (charlock) for each pupil. Other large flowered plants of this family may be substituted (see page 233). Magnifying glasses and large glass-headed pins or dissecting needles or forceps are valuable aids if time is not lost in distributing and collecting them. *Second lesson.*—One branch of wild mustard plant for each pupil, showing buds, flowers, and seed pods. *Third lesson.*—Three whole plants belonging to the mustard family, for each pupil. These need not be the same kinds for all pupils. Some smaller flowered kinds may be included.

References.—(1) Bulletins on Weeds. Winnipeg: Publications Branch, Department of Agriculture. (2) *Farm Weeds.* Ottawa: King's Printer. This has excellent color plates (price $2.00). (3) Bulletin, *Weeds and Weed Seeds.* Ottawa: Publications Branch, Department of Agriculture. (4) Refer also to the List of Publications of the Publications Branch, Department of Agriculture, Ottawa.

CHAPTER XXVI. PRESSING AND MOUNTING PLANTS.—(Page 245).

Teaching Projects.—(1) To press and mount four or more plants of the mustard family. (2) To use these mounted specimens in reviewing the characters of the family and in making familiar the wild and cultivated plants of the family that are found in the district.

Specimens and materials.—(1) For pressing plants each class requires a plant press. Two pieces of board (clear pine) 10 inches by 24 inches (half size of newspaper sheet) with newspapers, five sheets (ten pages) per pupil, make a good press. The pressure may be applied with screw clamps, cords, or straps, but weights such as bricks are simpler for pupils to use. About a dozen bricks are required. (2) For mounting pressed plants the material required is one sheet of tag Manilla paper 12 inches by 18 inches for each pupil. A suitable grade is described as "350 pound tough surface" quality. One foot of brown paper gummed tape will be sufficient for attaching specimens to the folders. For other methods of attaching see page 249.

References.—*The Teaching Botanist* by W. F. Ganong. Toronto: The Macmillan Co. of Canada, Ltd.

CHAPTER XXVII. PLANTS OF THE GRASS FAMILY.—(Page 251).

Teaching Projects.—(1) By examination of specimens of grasses and grains to find the outstanding characters of the grass family, other than flower structure. (2) By consideration of the uses made of grass plants to show the importance of the family to people. (3) To point out the particular characters of the family that make it more serviceable to people than other families. (4) To show that the great grass lands of the earth are the centres of agriculture and population and the main sources of the world's food supply.

Specimens.—One complete grass plant is required for each member of the class. These need not be alike but should include some cultivated grains and the commoner wild grasses (Fig. 195). One piece of turf, kept growing, is a means of constantly referring to the habit of growth of the grasses out-of-doors. For the school collection, grasses such as rice, sugar cane, bamboo, and others should be acquired as opportunity offers. If desired, some grasses might be pressed and mounted in place of some of the mustard plants.

References.—(1) *Fodder and Pasture Plants.* Ottawa: King's Printer (price $1.00). (2) *Farm Weeds.* Ottawa: King's Printer (price $2.00). (3) *Botany of Crop Plants* by W. W. Robbins. New York: P. Blakiston's Sons. (4) Bulletins on weeds. Winnipeg: Publications Branch, Department of Agriculture (for couch grass and a few other grasses that are troublesome weeds). (5) *Western Flora* by B. J. Hales. Toronto: The Macmillan Co. of Canada, Ltd.

CHAPTER XXVIII. THE CORN PLANT.—(Page 261).

Teaching Projects.—(1) By examination of the corn plant to show that it has the characteristics of the grass family and is therefore a member of

that family. (2) To find the flowers of the corn plant and show the relation of their parts to the parts of other flowers studied. (3) To indicate their adaptation for wind pollination.

Specimens.—Sufficient whole corn plants, fresh or dried, to permit each pupil to find for himself the positions of tassels, cobs, silks, nodes, leaf sheaths, roots. Separate immature cobs with husks intact, one for each small group of pupils. Top of stem with fresh clusters of stamen flowers (tassels), or old dry clusters together with smaller specimens showing stamens preserved in liquid.

References.—*Botany of Crop Plants* by W. W. Robbins. New York: P. Blakiston's Sons.

CHAPTER XXIX. THE SUNFLOWER FAMILY.—(Page 269).

Teaching Projects.—(1) To show by examination of familiar flowers found in the fall, that many of them are not single flowers but clusters of flowers. (2) To show how we may know whether or not a flower belongs to the sunflower family.

Specimens.—(1) Cultivated sunflower heads, one-half head for each pupil. (2) Heads of other plants of the same family both wild and cultivated (Figs. 208-212).

PART II. AUTUMN STUDIES OF ANIMAL LIFE

CHAPTER XXX. ANIMALS OF THE GREAT GRASSY PLAINS.—(Page 277).

Teaching Projects.—(1) To show that many of our domesticated animals are grazing animals and to point out how their different types of feet and the manner of their eating are related to their environment. (2) To show why grazing animals are suitable for domestication and how man has changed them to his advantage. (3) To show the importance of grazing animals in changing grass into more valuable products such as food and clothing.

Specimens.—(1) Dried feet of small grazing animals. Bones of the feet of the larger grazing animals wired together are valuable. (2) Skulls of various animals, such as cow, horse, sheep, pig.

References.—(1) *New Biology* by Smallwood, Reveley, and Bailey. Boston: Ginn & Co. (2) *Zoology for High Schools* by J. F. Calvert and J. H. Cameron. Toronto: The Educational Book Co., Limited. (3) *Lessons in Zoology* (well illustrated pamphlet) by V. W. Jackson. Winnipeg: Publications Branch, Department of Agriculture, (4) Send to the Agricultural College for bulletins on any breeds of cattle or other grazing animals that you may wish to study. (5) If you wish to extend your study to include dairying or wish to make a study of wool or leather, write for bulletins dealing with these problems also.

CHAPTER XXXI. RODENTS OR GNAWING ANIMALS.—(Page 291).

Teaching Projects.—(1) From keeping a caged animal, or observing animals in their homes, to give close personal acquaintance with the form and actions of a rodent animal. (2) To use this specimen as an example of rodents, their methods of living, and the results of their work. (3) To show that some rodents are harmful and others are useful. (4) To show that the problem of controlling rodents is chiefly due to their rapid increase when conditions are favorable.

Specimens.—(1) Any rodent animals in a suitable cage (Appendix, Secs. 16-18). (2) Specimens of wood or other material showing effects of gnawing. (3) A skull of a rodent showing the gnawing teeth.

References.—(1) *The Pet Book* by Anna B. Comstock. Ithaca, N.Y.: Slingerland-Comstock Co. (2) Bulletins on useful and harmful rodents. Ottawa: Publications Branch, Department of Agriculture. (3) Bulletin 33 (*The Brown Rat*), Bulletin 896 (*House Rats and Mice*), and Bulletin 369 (*How to Destroy Rats*). Washington, D.C.: Superintendent of Documents (price 15 cents each).

CHAPTER XXXII. CARNIVOROUS ENEMIES OF RODENTS.—(Page 305).

Teaching Projects.—(1) To emphasize, from reference to Chapter XXXI, the need of a check upon the increase of rodents. (2) To show by an example the balance between the carnivorous animals and the rodents and the harm that may come from interfering with the balance. (3) To show by examples the value of the carnivorous animals as a check upon rodents and as a source of furs. (4) To show, in a similar way, the importance of birds of prey in checking the increase of rodents particularly in places from which the carnivorous animals have been driven by the clearing and cultivation of the land.

Specimens.—(1) Use should be made of mounted specimens or good pictures of any carnivorous animals of Canada. (2) One mounted skull to contrast with the rodent skull is valuable for the school collection. (3) The printed animal outlines of the *Loose Leaf Field and Camp Note Book*, published by Slingerland-Comstock Co., Ithaca, N.Y., are suitable for pupils' use. (4) A collection of good animal pictures should be built up and mounted under glass. (5) Large charts should be used also. See catalogues of Central Scientific Co., Toronto, E. N. Moyer Co., Winnipeg, and Christie School Supply Ltd., Brandon.

References.—(1) *Economic Zoology* by A. M. Reese. Philadelphia: P. Blakiston's Son & Co. (2) *Fur and Game Resources of Manitoba* by V. W. Jackson. Industrial Development Board of Manitoba, Confederation Life Building, Winnipeg. (3) Bulletins on gophers and squirrels may be obtained from the Publications Branch, Department of Agriculture, Winnipeg. Write to this department for a list of its publications.

PART III. STUDY OF AIR

CHAPTER XXXIII. AIR.—(Page 313).

Teaching Projects.—(1) To show that air occupies space and has weight, and is therefore a form of matter. (2) To give some idea of the nature of matter.

Specimens.—See apparatus required for each experiment.

References.—(1) *General Science* by G. A. Bowden. Philadelphia: P. Blakiston's Son & Co. (2) *Junior Science, Book I* by J. C. Hessler. Chicago: Benjamin H. Sanborn & Co. This book is recommended for reference in *each chapter* dealing with the study of air.

CHAPTER XXXIV. AIR PRESSURE.—(Page 323).

Teaching Projects.—(1) To show that air exerts pressure and to account for this fact. (2) To illustrate how great air pressure is.

Specimens.—See apparatus required for each experiment.

CHAPTER XXXV. COMPRESSED AIR.—(Page 331).

Teaching Project.—To show that air can be compressed and that it is elastic.

Specimens.—See apparatus required for each experiment.

Reference.—*General Science* by O. W. Caldwell and W. L. Eikenberry. Boston: Ginn & Co.

CHAPTER XXXVI. USES OF COMPRESSED AIR.—(Page 335).

Teaching Project.—To show the use made of compressed air (*a*) in tires and balls, (*b*) in air brakes, (*c*) in air guns, (*d*) in pneumatic hammers and drills, (*e*) in submarines, (*f*) in diving bells, (*g*) in caissons.

Reference.—*General Science* by G. A. Bowden. Philadelphia: P. Blakiston's Son & Co.

CHAPTER XXXVII. AIR PRESSURE AT WORK.—(Page 342).

Teaching Projects.—(1) To show that drinking by suction depends upon air pressure. (2) To show that water rises up to the cylinder of a lift pump by air pressure. (3) To construct a simple barometer to demonstrate that air exerts pressure.

Specimens.—See apparatus required for each experiment.

References.—(1) *General Science* by O. W. Caldwell and W. L. Eikenberry. Boston: Ginn & Co. (2) *Our Environment* by H. A. Carpenter and G. C. Wood. Chicago: Allyn and Bacon.

CHAPTER XXXVIII. FIRE.—(Page 350).

Teaching Projects.—(1) To show that air is needed to support burning. (2) To show that air enclosed in a small space will not support burning indefinitely.

Specimens.—See apparatus required for each experiment.

CHAPTER XXXIX. NATURE OF AIR. WHAT IS BURNING?—(Page 355).

Teaching Projects.—(1) To show that only part of the air supports burning. (2) To explain what burning is.

Specimens.—See apparatus required for each experiment.

Reference.—*Open Doors to Science with Experiments* by O. W. Caldwell and H. D. Meier. Boston: Ginn & Co.

CHAPTER XL. OXYGEN, THE GAS THAT SUPPORTS BURNING. ITS RELATION TO RUSTING.—(Page 359).

Teaching Projects.—(1) To prepare some oxygen gas and show that it supports burning by uniting with the substances that burn; also to show that it is soluble in water and the importance of this to animals living in the water. (2) To give some knowledge of the abundance of oxygen. (3) To show what happens when iron rusts and to compare the rusting of iron (slow oxidation) with the burning of wood (combustion).

Specimens.—See apparatus required for each experiment.

CHAPTER XLI. CARBON DIOXIDE.—(Page 367).

Teaching Projects.—(1) To show that our foods contain carbon, that carbon unites with oxygen to form carbon dioxide, and that carbon in the foods that we eat unites with the oxygen in the air that we breathe to form the carbon dioxide that we breathe out. (2) To show how carbon dioxide behaves in order (*a*) to compare it with oxygen, (*b*) to show its use as a fire extinguisher, (*c*) and to explain its effect upon a person breathing it.

Specimens.—See apparatus required for each experiment.

PART IV. SPRING STUDIES OF PLANT LIFE

CHAPTER XLII. SPRING DEVELOPMENT OF TREES. CUTTINGS.—(Page 377).

Teaching Projects.—(1) To observe, on indoor and outdoor specimens of local trees, the opening of the buds in spring, finding that from each bud there comes a twig bearing leaves or flowers, or both leaves

and flowers. (2) To notice the arrangement of buds on twigs for help in the identification of local trees and shrubs. (3) Close observation of flowers of the maple and the willow or the poplar to show why some trees produce seeds while others do not. (4) To show the advantage that trees gain by opening their flowers before their leaves come out. (5) To show roots growing from tree branches kept in water, and from other stems, with application to the starting of new plants from cuttings.

Specimens.—(1) Branches of trees common in the district (large enough to show twigs), arranged as described on page 378, one of each kind per 12 pupils. (2) One twig with opposite and one with alternate buds or leaves for each member of the class. Each twig should show about six nodes. (3) Cuttings of tradescantia (wandering Jew) in water (Fig. 323); others to be started by pupils at home.

References.—(1) *Our Trees and How to Know Them* by Arthur I. Emerson and Clarence M. Weed. Philadelphia: J. B. Lippincott Co. This book is an excellent one from which to learn to recognize the trees and to find important facts about them. The pictures are many and excellent. Figures 314 to 321 in this text, *Science Indoors and Out*, are extracts from some of the large plates. (2) *Native Trees of Canada*. Ottawa: King's Printer (price 50 cents). This book has many good pictures and full descriptions of our trees. (3) *Forests and Trees* by B. J. Hales. Toronto: The Macmillan Co. of Canada, Ltd.

Chapter XLIII. Our Shade Trees and Forests.—(Page 388).

Teaching Projects.—(1) To show by reference to familiar examples out-of-doors, the usefulness of living trees for shade and shelter. (2) To show by examples and pictures how injury to trees may be avoided, and how a limb should be cut from the tree if necessary. (3) To show the great importance of our living forests based upon their uses while living and the products obtained from them. (4) To show the need for constant care to lessen the damage done to forests by insects, disease, and fire, and to emphasize the necessity of individual concern in this matter. (5) To show how our forests may be made to produce a perpetual crop for our use and for the use of future generations.

Specimens.—(1) Pictures of local use of trees for shade or wind-break, especially "before and after" contrasts. (2) Part of a tree stem with the bark eaten off by rodents. (3) Tree stems showing the injury caused by tight binding, etc. (4) A tree stem showing the right and the wrong way to remove a branch. (5) Forest pictures to show timber and pulp trees, forest streams, lakes, animals, etc. (6) Pictures showing forest fires and the work of forest patrols, and the planting of new forests.

References.—(1) See Nos. 2 and 3 of Chapter XLII. (2) *Forests of Canada* and *Circular 25, List of Forest Service Publications*. Ottawa: Director of Forest Service, Department of the Interior.

Chapter XLIV. Roots and Their Uses.—(Page 407).

Teaching Projects.—(1) To see on sprouted seeds the development of primary roots and their branches. (2) To collect and mount common examples of tap, fibrous, and tuberous roots. (3) To show the uses of roots to the plant: (*a*) absorption of soil water, (*b*) anchorage, (*c*) storage. (4) To review the use of roots to people as a source of food.

Specimens.—(1) Sprouted seeds. For method of obtaining sprouted seeds for a whole class see the Appendix (Sec. 9). (2) A thin tap root. (3) A fleshy tap root. (4) A fibrous root of grass or grain (best when very fresh or preserved in liquid). For preserving roots in liquid see the Appendix (Sec. 23). (5) Prop roots of corn.

References.—For this and the two following chapters, see any text-book of botany.

Chapter XLV. Stems and Their Uses.—(Page 411).

Teaching Projects.—(1) To see from outdoor observation the need for and uses of stems: (*a*) supporting flowers, ripe seeds, and leaves in exposed positions, (*b*) the propagation of new plants, i.e., cuttings, (*c*) storing food, (*d*) conveying sap upward and downward. (2) To see from specimens of grass stems their tubular structure and its advantages. (3) To observe out-of-doors the distinction between herbs, shrubs, and trees, and between typical tree shapes: (*a*) excurrent, (*b*) round-topped; also to notice the value of the forest type of trees for poles and lumber.

Specimens.—(1) A tendril climbing stem. (2) A twining stem. (3) A creeping stem. (4) A cutting from a stem showing roots (fresh or preserved specimens). (5) Straw stems (e.g., wheat) showing nodes and leaf sheaths, one for each pupil.

Chapter XLVI. Leaves and Their Uses.—(Page 419).

Teaching Projects.—(1) To see from a specimen the parts of a simple leaf: blade, petiole, veins, and green substance. (2) To explain that the green substance makes sugary sap, using soil water brought in by the veins and air breathed out by animals. (3) To show that the plant itself and all other living things depend directly or indirectly upon the sugar sap made in the leaves. (4) To show that living green leaves in sunlight change "breathed air" back to the condition of "fresh air." (5) To show that living green leaves in sunlight manufacture starch.

Specimens.—(1) Simple leaves of any kind that show veins clearly, one for each pupil. (2) One large leaf for demonstration. (3) Apparatus as indicated for experiments.

PART V. SPRING STUDIES OF ANIMAL LIFE

Chapter XLVII. Frogs and Toads.—(Page 425).

Teaching Projects.—(1) To show from living specimens the life history of the frog or the toad, with emphasis upon the changes that permit the adult animal to leave the water. (2) To show that the body temperature of the animal is similar to that of its surroundings and to compare it in this regard with warm-blooded animals. (3) To give an understanding of the value of frogs and toads as insect eaters.

Specimens.—(1) Eggs of a frog or toad. (2) A living frog or toad in a wire netting cage (Figs. 69 and 70).

References.—(1) *Handbook of Nature Study* by Anna B. Comstock. Ithaca, N.Y.: Slingerland-Comstock Co. (2) *Zoology for High Schools* by J. F. Calvert and J. H. Cameron. Toronto: The Educational Book Co., Limited. (3) *The Frog Book* by M. Dickerson. New York: Doubleday, Page & Co.

Chapter XLVIII. Fish.—(Page 439).

Teaching Projects.—(1) To show how to make an aquarium in which to keep fish and other animals. (2) To show, by examination of a living fish, (*a*) its external parts and their uses, (*b*) how it moves. (3) To show, from both a living and a large fresh or preserved specimen, how fish breathe. (4) To help the class to discover how fish obtain their food, and to learn what their food consists of.

Specimens.—(1) Sufficient minnows or other small fish to provide one for each small group in the class and a few for the school aquarium. (2) A large fresh fish or fish preserved in formalin, for examination of the gills.

References.—(1) *Freshwater Aquarium* by O. Eggeling and F. Ehrenberg. New York: Henry Holt & Co. (2) *Zoology for High Schools* by J. F. Calvert and J. H. Cameron. Toronto: The Educational Book Co., Limited. (3) *The Fish Resources of Manitoba.* Industrial Development Board of Manitoba, Confederation Life Building, Winnipeg. (4) Bulletin, *Fisheries of British Columbia.* Ottawa: Publications Branch, Department of Agriculture.

Chapter XLIX. Snakes.—(Page 449).

Teaching Projects.—(1) To show, by examination of a snake, the general form of the snake and how it differs in this respect from other animals studied. (2) By observation of a living snake, to show the way in which a snake moves and how its form and movement are suited to its natural environment. (3) To make a brief survey of the snakes found in Canada to discover whether snakes are of value to us.

Specimens.—(1) A living snake. (2) A preserved snake. (3) A live earthworm.

References.—(1) *Zoology for High Schools* by J. F. Calvert and J. H. Cameron. Toronto: The Educational Book Co., Limited. (2) *Economic Zoology* by A. M. Reese. Philadelphia: P. Blakiston's Son & Co.

Science Indoors and Out

Book One

PART I

AUTUMN STUDIES OF PLANT LIFE

CHAPTER I

MAKING A GOOD BEGINNING

When you build a snow-house in the winter, you do not cut snow blocks and pile them upon one another until you have planned where the house is to be, how large it will be, and where you intend to have the door. When you build a raft in the spring, you do not nail it together so far from the pond that you can never get it to the water's edge. When a woodman fells a tree, he plans which way he wishes it to fall before beginning to cut with his axe or saw. You would laugh heartily at a cook who mixed biscuits but forgot to heat the oven to bake them, or at a carpenter who came to his work without a hammer and saw, or built a garage too short for a car. You can readily see how foolish it would be to begin any of these tasks without first making plans.

When midsummer has come and gone, the prairies and the woods are swarming with living things. At that season every acre of field and woodland suggests a hundred questions about its grasses, grains, wild flowers, shrubs, and trees,

or about its birds, animals, and insect inhabitants. Walking across the fields or through the woods, we want to ask many questions: What is this? Why is that? Why does the rye grass nod its head (Fig. 1)? What musician makes that cheerful chirping, "zss, zss, zss," that seems to come from everywhere, and yet from nowhere in particular (Fig. 2)? Where are these ants going that have cleared tiny roads leading out from their nests in all directions? What makes those strange swellings on the stems of the golden-rod (Fig. 3)? And why is that goldfinch picking at the down of the thistle?

Fig. 1. Rye grass.

Fig. 2. The musician.

There seem to be so many kinds of plants and animals that we can never know them all, and so many questions that we can never answer them all. That is true, but a musician does not give up playing because there are too many pieces to play, and we do not cease reading because we can never read all the books and stories that have been written. Whether we know many things about plants and animals, or only a few, we shall find them interesting, and, as we become more familiar with them, we shall find more and more pleasure in watching them, and may learn many new and useful things about them.

Fig. 3. Golden-rod stem gall.

In our science course we are setting out to study plants and animals, their parts, and their ways of living. When we have completed the course, we should be able to answer many of our own

questions about living things. But our work with plants and animals requires even more careful planning than the building of a snow-house, or the making of biscuits, or even the building of a garage. We should be very unscientific, then, if we did not make careful plans for our work before we begin.

First, we shall need some "tools." As the carpenter cannot work without his hammer, saw, and square, so we cannot do good work without at least pencil, pen, note-book, eraser, and ruler. No good workman depends upon borrowing from others the things that he needs for his work.

Having secured our tools, we can next make plans for writing down what we discover about the living things of the fields and woods. As a store-keeper must be careful to send each parcel to the right customer, and not to charge the wrong person for it in his accounts, so we must keep our written notes carefully arranged and our diagrams carefully labelled, so that there may be no mistake about their meaning. To be useful, they must be correct as well as clear.

Anyone who has learned to write can learn to draw simple diagrams, not without effort perhaps, but with less effort than was required in learning to write. Be as careful in your drawing as nature was in making what you draw, and you will succeed.

We shall begin by considering some things that we already know, and shall make our first notes about them. This will help us to make a Good Beginning.

Uses of plants to people.—Under the heading "Uses of Plants to People", make short lists of the names of plants that are useful to us. To do this, first re-arrange the headings given on page 4, "Clothing", "Food", etc., in what you think is the order of their importance. Then write under each heading the names of three or more plants (the

most important one first, and the others in order) from which each of these is obtained. Keep these lists in your note-book.

Clothing	Food	Fuel	Shelter	Spices and Drugs
1.	1.	1.	1.	1 . . . .
2.	2.	2.	2.	2 . . . .
3.	3.	3.	3.	3 . . . .
etc..	etc..	etc..	etc..	etc. . . . .

To these add other lists under such headings as Sporting Goods, Vehicles, Printing and Writing Materials, Railways and Roads, Boats, Furniture, Threads, Cords, and Ropes, etc. Under each of these, mention the names of one or more plants used.

Such lists as these will remind us of the many things that we already know about plants and of the countless ways in which they are useful to us.

CHAPTER II

THE PARTS OF A SIMPLE FLOWER AND THEIR USES

Preparation.—Bring into the classroom a large wild flower, or one from the garden, or a cluster of flowers large enough for all the pupils to see. Have a few buds also. This classroom bouquet will be the group of living things about which we are thinking in this lesson.

Introduction.—We have tried to make a Good Beginning in our first chapter. In it we were recalling what we already know of the Uses of Plants to People. We made a written record of them that will often be useful for reference as we continue studying plants.

Now we are ready to look for more information that we may write down in an orderly way. This is what scientists everywhere are trying to do, to find information, and to arrange it and write it down, so that it will be useful whenever it is needed. But how can we get new information about flowers?

We cannot ask flowers questions in words, and *hear* their answers, but by examining them carefully we can *see* what they have to show us. Then we can *think* out what these things mean. In this way plants can tell us about themselves.

What have flowers to show us?—Think first of a flower that grows out-of-doors. Here is a poppy plant, for example (Fig. 4). What does it do all summer? Does it do anything but "just grow" and then die? If we watch a fully opened flower of any kind out-of-doors for a short time, we shall probably see some insect visitors come to it. They work busily in the flower for a moment, as if looking for something,

and then depart. What are they looking for? Where do bees get nectar from which to make honey?

Fig. 4. Poppy plant showing bud, flower, and fruit or pod. What is in the pod?

There is a bud on the plant. What will the bud do next? There is also a seed pod. What was it before it became a seed pod? Of what use are the color and the nectar to a flower? Some of these questions you can answer already; for the answers to the others we must ask the plant, by looking very carefully at it and thinking about what we see.

Collecting and keeping flowers.—In order to look at the flower carefully enough to see its parts, we must each have one in our hands. If the class is large, we should use garden flowers, or only those wild flowers that are very plentiful. Why? Many people forget that when they pick a flower it cannot make seeds and start more flowers for the next year. When we pick flowers in the woods or fields, we should always ask ourselves, "Am I leaving enough to make seeds, so that other people may find flowers in this place next year, and for many years? If my grandchildren dwell in this neighborhood, will they, too, find some of these blossoms in this place?" Let us not be like the greedy people who pick more flowers than they can use.

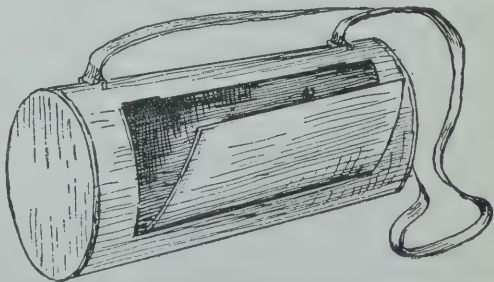


Fig. 5. A good collecting case keeps flower specimens fresh for several days.

Flowers for study keep best if they are placed in a "vasculum," or collecting drum (Fig. 5), immediately after they are gathered. A can or a pail with a lid will serve quite well. In the classroom, flowers may be kept in a large crock, or they may be wrapped in wet newspaper. They will remain quite fresh for several days in a cool, dark, moist place. If they are to be kept for a longer time, they may be preserved in liquid or pressed and mounted on cards. We shall learn how to do this later.

While we must collect flowers in order to examine them closely, we must not forget that flowers that have been picked can only die; they can never make seeds. The best place to enjoy the flowers is out-of-doors where they are growing. There they are much more interesting because, while they are growing, they are entertaining visitors and going on with their work of making seeds.

Finding the parts of a nasturtium flower.[1]—We have each in our hands a flower to which insect visitors were attracted when it was growing on the plant. Could insects flying about in the sunshine easily see this bright flower among the green leaves? Are the colors of any use? Could they find flowers in any other way than by seeing them? Insects have a very keen sense of smell, but they are short-sighted. Is perfume of any use to flowers? We, too, are attracted by the beautiful colors and perfumes of flowers. If we learn something about flowers, we shall better understand how insects and flowers help one another.

Now let us look carefully at the flower, and see what it has to show us. Can you find on the outside of the flower a circle of pointed, rather leaf-like parts (Fig. 6)? Look at a flower bud (Fig. 7) and see how well these parts protect it. Perhaps they have some other uses as well. Look for similar

[1]For this lesson we require for each member of the class a fresh nasturtium flower in which some of the anthers have opened to scatter their pollen.

parts in other kinds of flowers that you find out-of-doors. The name given to this outer protecting circle of flower parts is **calyx.** Each part of it is called a *sepal.* Notice that the long nectar spur is made by the lower part of the sepals on the upper side.

Fig. 6. Flower of nasturtium fully opened, waiting for an insect visitor.

The next circle of the flower is made up of the brightly colored *petals,* which together are called the **corolla.** How does the corolla help along the work of the flower? Can you see the "barricade" that keeps out unwelcome crawling insects? (See page 11.)

Now we come to the two most important circles of flower parts. They are inside the corolla.

Fig. 7. Nasturtium bud partly opened.

Each of the parts forming the circle just inside the corolla is made up of a stalk, bearing a little "head." Find one. These are called the **stamens** of the flower (Fig. 8). The head of the stamen is a little pouch or sac containing grains of *pollen* dust. In well-opened flowers, some of the little sacs, which are called *anthers,* will be open, and the pollen grains will be ready to fall off at the lightest touch. Some may have lost all their pollen and become withered. The stalk part of the stamen is called the *filament.* The pollen grains are very important, for without them the flowers could not produce seeds. We shall see what becomes of the pollen grains.

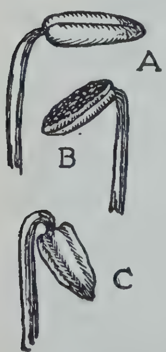


Fig. 8. Stamens of nasturtium; A, ready to open; B, open, ready for an insect; C, empty.

To do this we must find the innermost circle of the flower, the parts at its centre. In some flowers there is a

little circular cluster of these parts, but in the nasturtium they are all joined in one. This middle flower part you can find among the stamens by looking carefully for it. Its stalk has no anther, but has three little points that are sticky with a sugary liquid. It is called the **pistil** (Fig. 9). It is the part of the flower in which the seeds are produced. Its three-pointed top is called the *stigma*; its stalk is called the *style*; and the large rounded part at the bottom is the *ovary*.

Fig. 9. Pistil of an older nasturtium flower.

Insects and pollen.—Now think again about the insect visitors that come to flowers.

When a bee alights on a blossom and searches about in it for nectar, it cannot help rubbing against the stamens. When it does so, its hairy body and legs are thickly dusted with pollen grains. As it works about in the flower, the bee touches not only the stamens but also the pistil, and some of the pollen clinging to its body is rubbed off on the three little points at the top of the pistil. As the pistil is able to produce seeds only after it has received pollen grains, the insect visitors are important helpers of the flowers in their work of making seeds. The bees take home some of the pollen for food, but the flowers have plenty to spare.

We have now seen the four circles of the flower—calyx, corolla, stamens, and pistil,—and we understand how the pollen grains are carried by the insects from the stamens to the pistils.

Practical Exercise

(1) Lay out one of the upper petals and one of the lower petals that you removed from your flower, and draw their outlines natural size. Follow the method of working shown in the sample from a pupil's notebook given on page 11. Do not copy these drawings, but draw from your specimen. Notice how carefully this page was planned before the diagrams were begun. It was framed and divided by light pencil lines

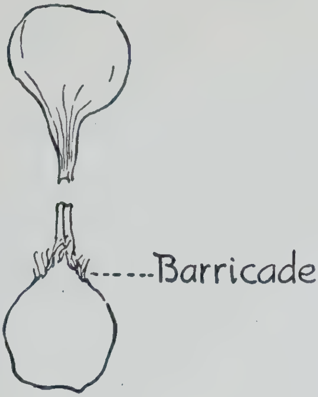
into four equal rectangles, a space being left at the bottom of the page for title, initials, and date. Then a diagram was carefully drawn in each rectangle, leaving room for its labelling, title, and size. All words not in sentences in your note-book should be done in a simple style of "print writing." "×1" means natural size; "×3" means that the diagram is three times as large as the specimen. (2) Draw one stamen, three times natural size, and label its parts. (3) Draw a diagram of the pistil ×3, and label its three parts.

How the pistil makes a seed pod[1]**.**—Some of the flowers that we examined carefully in the last lesson were older than others, and in these perhaps the pistil had already received some pollen and had begun to produce its seeds. Let us now examine the pistil of a nasturtium flower that is beginning to wither. Take off the corolla and the stamens. Do this carefully with a knife or needle or forceps, and keep the parts for your drawings. Turn down the sepals of the calyx to make a convenient handle with which to hold the flower, as shown in Figure 9.

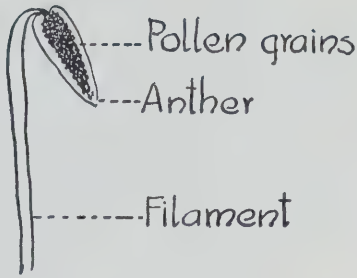
Find again the three little points at the top of the pistil to which the pollen sticks when a "dusty" bee touches them. This sticky part at the top of the pistil, you will remember, is called the stigma. It is not always in the form of three points like that of the nasturtium. The stigma is held up by the style or stalk part, and it stands upon the ovary. Inside the ovary there are little round bodies called the *ovules*, that will grow into seeds if pollen is placed on the stigma.

If only one pollen grain has been placed on the stigma by an insect, only one of the ovules will develop into a seed, but if the stigma has received plenty of pollen, three seeds will be formed, one in each division of the ovary. The ovary itself forms the seed pod. The three points of the stigma and the three divisions of the ovary show that the

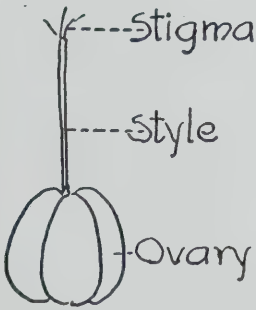
[1]For this lesson we require nasturtium flowers in which the corolla has withered and the ovary of the pistil has begun to form a seed pod.



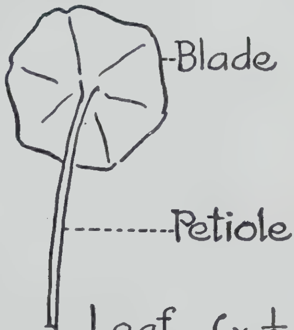
Upper and Lower Petals (×1)



Stamen (×3)



Pistil (×3)



Leaf ($\times \frac{1}{2}$)

The Flower and the Leaf of Nasturtium

E·H·A. Sept 12th

pistil in this flower is really made up of a circle of three pistils joined together, each producing one seed.

Now write down what you have found out about the flower of this plant. The following Question Outline will help you to keep your note-book record complete. Your note-book story need not be long, but to be of any use it must be very clear and quite accurate. When you write a sentence, always write it in good English and say exactly what you mean.

Question Outline

(1) What is the name of the outside circle of the flower? (2) What is each part of this circle called? (3) What is the use of this circle? (4) What is the corolla of the flower? (5) What is the use of the bright colors of the flowers? (6) Where are the stamens? (7) What do the stamens make for the flower? (8) Where did you find the pistil? (9) Of what use is the sticky substance on the stigma? (10) What grows in the ovary of the pistil? (11) What is formed by the ovary itself? (12) What part of the flower of a pea or sweet pea do you think forms the seed pod?

CHAPTER III

HOW THE PEA FLOWER MAKES A SEED POD AND SEEDS

Preparation.—Bring into the classroom for this lesson some flowers of garden pea or sweet pea or others like them. Bring also some old withered flowers and some pods, one for each member of the class.

Parts of the flower.—Having found the four circles of parts in a simple flower like the nasturtium, we shall have very little difficulty in finding them in another flower that is not quite so simple. Look carefully at the flower of the pea or sweet pea, viewing it from one side (Fig. 10). Can you see the calyx and the corolla? The sepals of the calyx are joined together. How many sepals are there? Now hold the flower in the position in which it grows, with its stalk vertical, and look at it from the front, as a bee might see it when flying towards the plant (Fig. 11). Would the bee see the flower's full display of color? Would it see an inviting landing stage? This must be important to an insect, especially in windy weather.

Fig. 10. Side view of sweet pea flower.

Fig. 11. Face view of sweet pea flower showing standard and landing stage.

The corolla of the pea flower is very irregular, and the petals have been given special names. The large upper one spreading out in full view of an approaching insect is called the *standard*. The two petals forming the sides of the landing stage are the *wings*, and the middle canoe-shaped part is the *keel* of the flower. Compare your flower with Figures 11 and 12, but do not pull it apart until later.

Two petals are joined together to form the keel. How many petals are there altogether? As we look at the outside of the flower, we cannot see the stamens or the pistil. Where are they, and how does the bee touch them and become dusted with the pollen?

How the pistil of the pea flower receives pollen.—If we carefully watch a bee or any other large flying insect when it alights upon a pea flower, we shall be able to answer our questions, but if we cannot find an insect working in a pea flower, we may imitate its actions artificially.

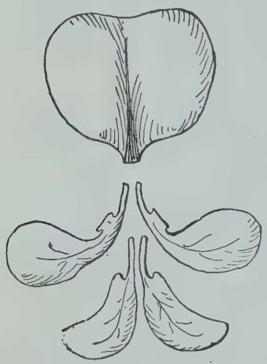


Fig. 12. The five petals of a sweet pea flower.

To find out what happens when a bee alights upon the flower, very gently press downward on the tip of the keel, or on its sides, as an insect would press in standing upon it with its six feet. A pencil eraser or the finger-tips may be used. When the wings and keel are pressed downward, the stamens and pistil spring out through the opening along the upper side of the keel. If an insect were standing on the keel, when this happens, would it be dusted with pollen? The insect must open the flower in this way, before it can obtain the nectar. The nectar is found inside the tube formed by the filaments of the stamens. Small insects are therefore unable to reach it, because they are not sufficiently heavy to "trip" the flower.

When the pistil of a flower receives pollen, it is said to be *pollinated*. When it receives the pollen from its own stamens, it is *self-pollinated*, but when it receives pollen from the stamens of another flower of its own kind, it is *cross-pollinated*. Some flowers can produce good seed after self-pollination, while others can produce good seed only after cross-pollination has taken place. If a pistil receives

a mixture of pollen from its own stamens and those of another flower, it uses the "strange" pollen and is cross-pollinated. Nearly all flowers produce better seed when cross-pollinated.

Now we have seen how pollen is carried to the pistil in flowers of the nasturtium and the pea. What takes place in the pistil after it has received pollen?

The ovary of the pistil becomes a seed pod.—Remove the corolla from a withered flower. You find that the stamens form a tube around the pistil. To remove this tube, split it with a pin or needle and peel it off (Fig. 13). You now have the pistil standing alone within the calyx cup. Count the sepals of the calyx; then split it and turn it downward. Hold the pistil up to the light. You will be able to see the young seeds in its ovary. Along which joint or seam of the pod are they attached? Hold the pistil in its natural position, with the style pointing upward, and make a drawing of the side view. Split the ovary carefully along the lower edge with a pin, and open it to see the seeds. Show them in your drawing.

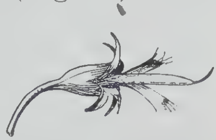


Fig. 13. Sweet pea flower with corolla removed and stamen tube opened.

Now, if you open an older pod, you can understand how the seeds came to be there. You have seen how the pistil of the pea flower obtains pollen, and that after pollination its ovary grows into a seed pod with seeds in it.

Question Outline

(1) What four kinds of parts have you found in the pea flower? (2) How many sepals has the calyx? (3) What parts of the corolla form a landing stage for insect visitors? (4) Would small insects such as flies be able to open the pea flower and obtain its nectar? Why? (5) What is self-pollination? cross-pollination? (6) Which produces better seeds? (7) What becomes of the corolla after pollination of the pistil? (8) Why is it no longer needed? (9) What becomes of the pistil? (10) Is the stigma needed? (11) Where are the seeds formed?

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CHAPTER IV

MAKING AND ARRANGING A COLLECTION OF SEEDS AND FRUITS

All seed vessels are fruits.—We have found that the nasturtium flower produces a seed pod of three divisions, each with one seed (Fig. 14), and that the pea flower produces a long, narrow pod with a row of seeds in it (Fig. 15).

Fig. 14. Fruit of nasturtium.

Do the pistils of other flowers also grow into seed pods with seeds? Have you seen the seed pods or seed vessels of the poppy, the snap-dragon, or the peanut (Figs. 16 and 17)? These are all pods containing seeds. What about the "bunches of keys" of the maple or ash trees (Fig. 21)? Are they seed pods? This is difficult to decide, but at least each of them has in it a seed that will grow to a tree. Each of the tiny pods in the fluffy white head of the dandelion has a single seed, and each pod has a little parachute that carries it in the wind (Fig. 19). What about the cherry, the tomato (Fig. 32), and the peach? Are they seed pods containing seeds? We do not usually call them pods, but they are soft, fleshy seed vessels. The poppy pod, the peanut, the maple keys, and the cherry fruits are all seed vessels containing seeds. Each of them has been formed from the ovary of a pistil, as the pea pod was formed from the ovary of the pistil in the pea flower. *The ripened ovary with the seeds in it is the fruit of the plant.* Some fruits possess hooks, parachutes, or other additional parts.

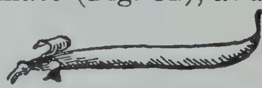


Fig. 15. Fruit of sweet pea.

Why seeds must scatter widely from the parent plant.—When a fruit has been formed from the ovary of the pistil and the seeds are ripe within it, what is needed next? Think what would happen if all the seeds of a maple tree or a dandelion or a poppy fell straight to the ground below and all began to grow at the same time. They would be so crowded that they would all be taking water and food from the same soil, and would be so shaded by the parent plant that most of them would die. Therefore, in order to avoid overcrowding and starving one another seeds must scatter widely from the parent plant.

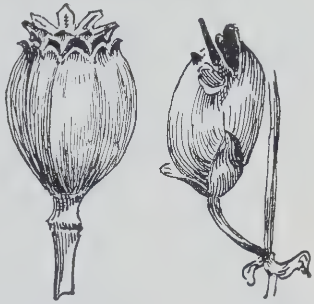


Fig. 16. On the left is shown fruit of poppy; on the right, fruit of snap-dragon.

By spreading widely seeds are able not only to avoid overcrowding but also to find all the places in the country that are suitable for their growth. Moreover, when they are widely distributed, there is less danger of all of them being destroyed by fire, flood, disease, or other misfortune that might befall them.

Various kinds of fruits have many and interesting ways of scattering their seeds or of travelling with their seeds to distant places where they may have a more favorable chance to grow. Fruits that have more than one seed usually open, unless they are fleshy, and the seeds travel separately. Sometimes, therefore, the traveller is a fruit, and sometimes it is a seed. The best way to understand the methods by which seeds and fruits travel is to make a collection of various kinds, and, by examining them carefully, to let them tell us about themselves.

Fig. 17. Fruit of peanut plant. Have you found the young plants in its seeds?

We shall first plan our collection; then, as various kinds of seeds and fruits are brought in, we can fit them into our plan and gradually build up a complete collection.

Mounting the seed vessels or fruits.—There are many ways of mounting fruit and seed collections. For your own collection any one of them might be satisfactory. Many good collections of seed vessels are mounted by laying them out on clear, white cotton batting, spread on a stiff card or a wooden back, and placing over them a piece of glass. Some kinds may be attached directly to cards, and others may be placed in holes made with a gun-wad punch in a thick piece of cardboard or linoleum. Gummed tape made of brown craft paper, three-quarters of an inch wide, such as is used to fasten parcels, is good for mounting and for binding around the edges of cards and glass. It stays on glass better if moistened with 10 per cent glycerine solution instead of water.

Fig. 18. Test-tube mount for dry fruits and seeds. The specimen and cotton plug are in place, but the label has not yet been put on.

For a class collection, which can be passed about for everyone to see, and to which new specimens may be added at any time, one of the best mounts is a set of test-tubes. These should be fitted with cotton plugs for stoppers and labelled with the name of the seed or fruit and the time and place of collection (see Fig. 18). A satisfactory label may be made from gummed paper tape. If the tape is stuck around the test-tube near the top, it greatly strengthens the glass. If preferred, the label may be on a strip of paper inside the tube with the specimen. In this form it is more easily altered. On the label should appear the name of the fruit or seed, its method of travelling, the collector's name or initials, and the date.

For the fleshy fruits, which are preserved in 5 per cent formalin solution, sample tubes, shell vials, or heavy test-tubes fitted with corks may be used. Olive bottles are suitable for larger kinds and sealers for the largest. Many other kinds of mounts may be devised. Perhaps your school laboratory has something specially suitable for this work.

Bring into the classroom as many kinds of ripe seed vessels as you can find, from all kinds of plants, but select good specimens with seeds still in them when possible. Mount them carefully by whichever method you find suitable, and label them as completely as you can. There may

be some that you cannot name at once. In these cases, try to find the flower or the whole plant, and find out its name.

Our plan for arranging the collection of fruits and seeds.— We might arrange the fruits by their sizes, by their colors, by their taste, or by something else that we can notice about them, but the most interesting thing about fruits and seeds is the way they *travel*. We shall therefore arrange our

Fig. 19. Tufted fruits of dandelion. Only a few are left on the end of the stalk.

Fig. 20. Fruit of milkweed. Tufted seeds are escaping to travel in the wind.

Fig. 21. Winged fruits of maple and ash. Do these fly long distances? Look for them drifting with the snow in winter.

collection of fruits and seeds according to their methods of travelling. Build up your collection to show the following kinds of fruit and seed travellers:

FRUIT AND SEED TRAVELLERS

A. Fruits and seeds carried by the wind:

1. *Tufted fruits*; e.g. dandelion (Fig. 19). *Tufted seeds*; e.g. milkweed (Fig. 20), willow.

2. *Winged fruits*; e.g. maple, ash (Fig. 21). *Winged seeds*, e.g. gladiolus (Fig. 22).

Fig. 22. Winged seeds in fruits of gladiolus. Do they all fall out at once? What advantage do they gain by falling on different days?

Fig. 23. Fruit of sour dock. Notice the three wings. The swellings between them are three air sacs, between which is the one seed.

3. *Shaking fruits*; e.g. poppy (Fig. 16), snapdragon (Fig. 16). The stems of these plants become very stiff, and when there is a strong wind, they quiver, throwing out seeds through their small openings, a few one day, and a few another, in different directions as the wind changes.

4. Seeds of *tumble weeds*; e.g. Russian thistle, tumbling mustard. The tumble weeds are bushy plants, which break off near the ground and roll along before the wind, breaking open their pods as they go, and dropping their seeds (Fig. 24). They are not always weeds, but this is the name given to them.

Fig. 24. Tumble weeds roll across the prairies until they come to a fence or bush or other obstacle. These are Russian thistle.

B. Fruits and seeds carried by water:

1. *Fruits with air sacs* which act as floats; e.g. sour dock (Fig. 23).

2. *Fruits with a fibrous husk*; e.g. cocoanut (Fig. 25).

3. Fruits and seeds which have no special floats but which are sufficiently *light in weight* to float upon water for some time. Floating fruits and seeds begin to grow when they are washed

up on shore. This explains the presence of willows and other trees along the rivers, also of cocoanut palms on oceanic islands.

C. Fruits and seeds carried by people and animals:

1. *Burs with hooks*; e.g. clot-bur, burdock (Figs. 26 and 27).

2. *Burs with barbs*; e.g. beggar's ticks (Figs. 28), spear grass (Fig. 29).

3. *Fruits and seeds of very small size* carried in the mud on the feet of birds, animals, and people. Think of the

Fig. 25. Fruit of cocoanut with fibrous husk. It floats. How do these palms start on new oceanic islands?

Fig. 26. Fruit of clotbur. Notice the large and small hooks.

Fig. 27. Head of fruits of burdock. The separate fruits fall out one by one as the head breaks apart.

Fig. 28. Beggar's ticks with barbs pointing backward.

common pathway weed, knot grass, which appears wherever a path is kept beaten. How do the seeds travel from the old paths to new ones?

4. *Seeds of fleshy fruits,* thrown away after the fleshy part has been eaten. The seeds are not eaten because of the woody core (apple, Fig. 33), the bitter taste (orange), or the hard shell (peach). Some very small hard seeds that are swallowed are so indigestible that they pass through the digestive systems of birds or animals without being injured, for example, figs and cherries (Fig. 31).

5. Seeds of any kind, especially those of *farm weeds*, carried from place to place on wagons, automobiles, or farm machinery, or in straw or hay used for packing goods.

6. Seeds of *cultivated plants* carried to all parts of the world for the purpose of growing new crops. Collect heads of wheat, oats, barley, and other field crops. Mount these, and also some threshed grains of each variety.

Fig. 29. Barbed fruit of porcupine grass or spear grass. The bent shaft twists with moisture, causing the head to bore into the ground, into animals' fur, or into people's clothing. Whole flocks of sheep have been killed by this bur. It pierces the skin and enters the body, being pushed by the twisting shaft.

Fig. 30. The fruit of the caragana springs open suddenly, and the two valves twist, throwing out the seeds. Collect some ripe pods and lay them on a plate in a warm place.

Fig. 31. Fleshy fruits of cherry. The one hard seed is very indigestible.

Fig. 32. Tomato, a fleshy fruit with many seeds. It is in reality a large berry.

Fig. 33. The apple is a fleshy fruit that has its seeds protected by a woody core. People or animals eating the fleshy part throw away the core, scattering the seeds far from the parent tree.

D. Seeds scattered by the springing open of the pod:

Caragana and balsam are examples of this class (Fig. 30). Find caragana pods on the hedges and bring them

indoors when nearly ripe. As they become dry, they will spring open and twist, throwing out the seeds.

Perhaps you will find a fruit or seed that is not carried by any of these four carrying agents. If so, make a fifth division, and look for other fruits and seeds that belong in it.

Question Outline

(1) Keep a record in your note-book of the fruits and seeds that you have in your collection, and of the method by which each of them travels. Name each fruit or seed, and draw a diagram or write a description of one from each of the groups A, B, C, and D.[1] (2) Include in your collection the common grains and a few of the common kinds of garden seeds. (3) For Section 6 of Class C of your collection try to secure seed vessels of all the main crop plants, first those of Canada, then those of other parts of the world. Perhaps you could exchange some with pupils in other provinces and other countries.

[1]Distribute the mounted specimens and exchange them in the class until each member of the class has made a diagram of each type.

CHAPTER V

HOW ONE SEED PRODUCES MANY NEW SEEDS

Preparation.—Bring from a field a few full-grown wheat plants to show the class. Mount one of them for the school collection. (See Appendix, Sec. 15.)

The extra seeds of the wheat plants.—One grain of wheat planted in the soil produces a wheat plant that has a root and several branches or stems similar to the other grass plants. Look carefully at the wheat plant (Fig. 34). How many stems and how many heads of wheat has it produced? Thresh out the heads, and separate the wheat from the chaff so that you may count the grains produced from the one grain that was planted in the field last spring.

If one of these plants has four stems, each bearing a head of wheat, and each head has in it eight grains of wheat, there will then be thirty-two grains on the plant that grew from one grain. Not all of these will be as large as the grain that was planted in the soil, because farmers always screen out the small grains and sow only the larger stronger ones. Altogether, however, the thirty-two grains will probably be at least twenty times as large and heavy as the one from which they grew. After making this count, we may say that, if a farmer sows one bag of good wheat (1¾ bushels) on one acre of good ground, allowing for some grains that do not grow, he may expect to have at threshing time sixteen or more bags of wheat (Fig. 35). If there is not enough rain during the summer, or if there are many weeds or insects in the field, the yield will probably not be as large as this. Sixteen bags of 1¾ bushels each, or 28 bushels, is a good yield from one acre.

What does the farmer do with his sixteen bags of wheat? He could sell it all, but then he would have none to sow in his fields the next year. How many of the sixteen bags must be put away for seed if he wishes to grow the same amount of wheat again next year? Farmers usually sell all the new wheat that they do not require for seed. After they have sold it, it goes to the millers, and then to the bakers who make it into the world's bread supply for the following year. Some of it is used in the form of breakfast foods or other wheat products, but most of the flour part goes into bread. In some countries cheaper bread is made from rye flour.

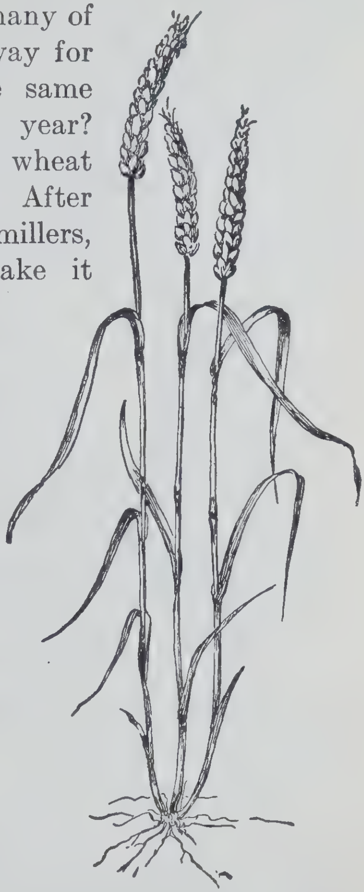


Fig. 34. A wheat plant that grew from one grain of wheat. How many "heads" has it? How many grains grew on each head in your specimen?

Thus we see that the bread supply of the world is obtained each year from the *extra seeds* produced by wheat plants, seeds that are not needed for planting the next year.

The extra seeds of wild plants.—We have seen that the wheat plant produces more seeds each year than are needed for the next year's crop. Do wild plants also produce extra seeds?

How many seeds are grown on a plant of Frenchweed or peppergrass?[1] —To answer this question bring into the classroom a medium-sized bushy plant that has seed pods on most of its branches (Fig. 36). This plant

[1]Any annual plant may be used that produces a considerable number of pods that do not fall when ripe. Pods with only a few seeds in each are better than those with many seeds. Some of the pods should have their seeds when examined, but not all need be full.

grew from *one seed* that was ripened in one of the pods on a last year's plant. That one seed of last year has this year produced all the seeds that are on this plant. Let us find how many seeds have grown from the one seed that ripened last year.

With scissors clip off the branches of the plant, giving one or two to each member of the class so that the pods may be counted. In this way the total number of pods on the plant may be quickly found. Next, find the average number of seeds in each pod. To do this, let each pupil thresh out a ripe pod and find out how many seeds it contains. Then calculate the number of seeds on the whole plant. How many of these seeds are needed to produce another plant to replace this one when it dies? *Only one seed.* Why, then, does the plant produce so many extra seeds?

Fig. 35. If a farmer sowed one bag of wheat on each acre last spring, how many bags may he expect to harvest in the autumn? How many of these must he save for seed again next spring? What will become of the rest?

What becomes of the seeds of the Frenchweed or the peppergrass plant?—In our study of fruits and seeds we learned how some kinds of seeds are scattered. What becomes of them after they are carried away? If, during the autumn, you could have watched all the seeds of the parent plant from which our specimen came, you would have seen them ripen gradually and blow away in different directions each day. What happened to them after they were carried away by the wind? "Some seeds fell by the wayside, and the fowls came and devoured them up: some fell upon stony places, where they had not much earth: . . . and they withered away. And some fell among thorns; and the thorns sprung up, and choked them. . ." Doubtless, also,

some of the seeds of the plant were crushed under feet or wheels, some were washed away by rains into the streams or rivers, and others were eaten by insects or birds. Some may have been buried too deeply to grow, and others not deeply enough; some may have grown to small plants and been eaten by animals along with the grass about them. There are many ways in which the seeds might have been destroyed.

When we think of all the accidents that might have happened to them, and when we remember that practically all the suitable growing places are already occupied by other plants, we are not surprised to learn that, in spite of having so many seeds, these plants do not greatly increase in number from year to year. There are about as many of them this year as there were last year, and there will be about the same number again next year. It is clear, then, that of all the seeds produced by each plant only an average of *one seed* each year survives and grows to full size, producing seeds again.

Fig. 36. Peppergrass plant with seed pods. How many pods did you find on your specimen?

Now we understand why plants produce a great many seeds. The explanation is that so many seeds are wasted in the chance dispersal by wind, water, animals, and other agents, that only those plants which produce a large "margin of safety" of seeds have been able to survive.

The extra seeds that wild plants produce are destroyed, but the extra seeds produced by cultivated plants provide us with food. We try to prevent birds, animals, and insects from destroying these plants, and when they are ripe, we

harvest the seeds and keep them dry and clean. In this way people make use of the large number of *extra seeds*, the "margin of safety" seeds, that are produced by the most useful food plants.

Question Outline

(1) Count the number of stems in a dozen wheat plants from a certain field, and find the average. (2) Count the number of grains in the heads and find the average number on each plant. (3) How many bushels of wheat should this field produce for every bushel sown? (4) Try to estimate the number of seeds produced on some common tree. If only about one new tree grows for each one that dies, how many successful seeds does a tree produce in its whole life-time? (5) What becomes of the extra seeds, or "margin of safety" seeds, produced by wheat? (6) What becomes of these extra seeds in the case of the trees, and the Frenchweed or other wild plants? (7) Why are plants of the Frenchweed (mustard) family very successful and troublesome weeds?

CHAPTER VI

HOW PLANTS PREPARE FOR THE HARDSHIPS OF WINTER

Preparation.—Bring into the classroom some small branches from evergreen trees that have not been planted for ornament. If evergreens are not plentiful, preserve these branches in liquid for the school collection.

Why plants need protection in winter.—Winter in our climate is a time of hardship for most plants as well as for other living things. People and animals feel the cold and seek to escape from it by increasing their body coverings, by building warm homes, by digging holes in the ground, or by protecting themselves in some other way. Where do frogs go when the weather turns cold? How do gophers live through the cold season? What do birds do?

The animals and people that survive the winter in the colder regions of the earth all have some means of protecting themselves against the cold. Plants also need protection to prevent them from being killed by the hard conditions of winter, but they cannot move from one place to another once they are rooted, nor can they build a shelter about themselves. They can withstand the hardships of winter only by changing themselves in preparation for the winter season before it arrives.

Plants probably do not suffer from the cold as animals do, but they are in danger of being killed by *freezing* or by *drying out*. The winds of winter are very dry, and, while the ground is frozen, the roots can take in very little, if any, moisture from the soil. Plants are also in danger of being *broken by the snow* while they are frozen stiff. Have

you ever seen trees "caught" by a snow-storm in the early autumn before they had shed their leaves, or in the spring after the leaves were out? Many large trees are broken by the weight of snow lodged upon their leafy branches.

Plants that winter over with little change.—1. *The evergreens.*— There are some plants, especially some trees, that do not seem to change much in preparing for winter,

Fig. 37. Which of these trees might be damaged by snow? Why? Notice that the main stem of the spruce "runs out" at the top while the elm is round-topped.

but seem to be *always ready* for winter. The evergreen trees —spruce, pine, cedar, and others—are "ever green" because all of their leaves do not fall off at any time until the tree dies. A few fall each year from the older twigs, but the tree is well covered with leaves throughout the year.

Why are the evergreens not broken by snow lodging on their leaves and branches? Notice the conical shape of most of these trees (Fig. 37). The upper branches are short and strong enough to carry all the snow that can lodge upon them. The lower branches, being long and slender,

droop by their own weight to a sloping position. The snow falls chiefly on their outer ends, the inner part being covered by the branches above. Thus laden with extra weight, they bend down a little further, and the snow slides off. Notice how much less likely to be broken by snow are these trees than are trees with trunk and branches in the form of a "Y" (Fig. 37).

The leaves of the evergreen trees of cold climates are very narrow, and thicker than other leaves. Examine your specimens. They are shaped like thick needles, some being long and others short, but all fairly stiff (Fig. 38). Such leaves are so strong that they are not damaged by snow or strong winds. Because of their small surface and thick, leathery skin, the evergreen leaves do not dry out and wither as broad leaves do. In winter the sap of the evergreens thickens, somewhat as molasses thickens in cold weather, and therefore it does not freeze and injure the leaves.

Fig. 38. Leaves of white spruce. Why are these leaves not damaged by wind, frost, or snow?

Having looked at an evergreen tree to see what it has to show us, we have noticed a number of points. Its needle-shaped, leathery leaves are protected against drying out by winter winds. Its sap thickens gradually and does not injure the delicate living parts when frost comes. Its conical shape, with slender branches, protects it against damage by snow. We have found, in fact, that it is prepared for winter weather at any time.

2. *The rosette plants.*[1] — There are some other kinds of plants that are so hardy that they are always ready for winter. Many of these you can readily recognize by their rosette habit of growing in the autumn. Find some rosette plants in the garden or grain fields, or at the sides of graded roads (Figs. 39 and 40). They have very short stems, and their leaves are all spread out in a circle flat upon the ground. They remain in this rosette stage throughout the winter.

Fig. 39. Flat autumn rosette of tumbling mustard. These leaves spread out flat upon the ground.

Fig. 40. Autumn rosette of Frenchweed. The plant has grown this far and is ready for winter. When will it ripen its seeds?

Not all rosettes of leaves are able to live through the winter; for example, the leaves of the dandelion do not survive the winter, unless well covered, though its root lives through a number of winters. Several plants of the mustard family begin to grow from seed in the autumn, and before winter sets in are able to produce a rosette of very hardy leaves that can live through the winter even in our cold climate. The Frenchweed (Fig. 41) is one of these hardy plants, and its rosette habit makes it a very difficult weed to destroy. It can begin to grow in the autumn and

[1]A tall specimen of Frenchweed, peppergrass, or other rosette type of annual with its seed pods should be shown to the class for recognition. Then a winter rosette of the same kind of plant should be seen closely by each member of the class. The rosette may be conveniently mounted with its root through a hole in a card, or it may be planted in a box or pot and allowed to grow to the flowering stage. Preserve good specimens of each type.

live through the winter. It ripens its seed early the next summer, long before the crop is ready to harvest. Its seeds are then ready to grow in the autumn and ripen again before the next crop ripens on the field. The Frenchweed is able to survive the drying winds and the freezing and thawing of the winter season even in its flowering stage, if it is fortunate enough to be sheltered by a covering of snow. These weeds, like the evergreen trees, are always prepared for winter.[1]

Fig. 41. This is the Frenchweed plant as it grows from seed in the warm, moist weather of spring. Compare it with autumn-grown plants.

Plants that prepare for winter by shedding their leaves. — The evergreens and the rosette plants are able to survive the cold, dry winter simply because they are very hardy. They are not injured by wind, frost, or snow and are therefore ready for winter at any time.

All the broad-leaved trees and shrubs of the prairies, however, shed their leaves in the autumn as a preparation for winter. No broad-leaved evergreen trees are able to live through the intense cold of a prairie winter, though many of them survive the winter in other parts of the world. Holly, for instance, grows in the warmer parts of Canada, but in our climate only the deciduous (*de*, down, *cadere*, fall) kinds of broad-leaved trees can survive.

The deciduous trees do not shed their leaves without first making ready to do so. If each leaf fell off and left an open wound, the sap would leak out, and the tree would die. Instead of thus injuring itself, the tree makes a remarkable

[1]Tumbling mustard, shown in Figure 39, is another noxious weed with the rosette habit.

preparation for shedding its leaves and growing new leaves the next spring. To see how this is done, we must each have a branch from a shrub or tree.

Preparation.—For each member of the class, find a branch that has one or more twigs along its sides in addition to the end twig (Fig. 42). If branches can be found with the leaves just ready to fall, they are the best for this purpose; but branches from which the leaves have fallen, leaving the buds, will show us quite well what we are looking for. These

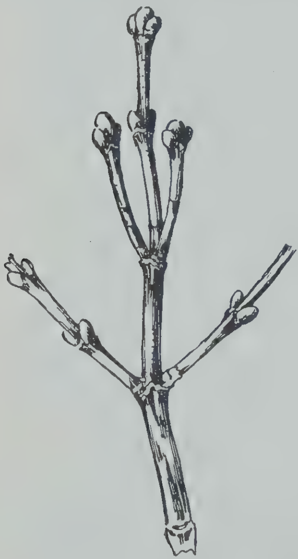


Fig. 42. Small branch of maple in winter condition, showing twigs and buds. Notice the arrangement in pairs opposite.

Fig. 43. Bud growing during summer in the axil of a leaf. Every leaf on the tree has a bud in its axil. On maple and other trees the bud is hidden by the end of the petiole.

may be found in any willow clump, or among branches cut from maple, elm, or other trees in pruning, or from a hedge or shrub that can spare them to advantage provided that they are cut by someone who knows how it should be done.

The layer of cork.—Now examine the branch and find below each bud the leaf scar from which the leaf fell (Fig. 44). Figure 43 shows how the leaf and its bud were placed. The bud was in the angle between the leaf-stalk, or petiole, and the twig. This angle is called the **axil** of the leaf. The

bud grew during the summer and was fully grown by the early autumn.

Before the leaf fell, a layer of cork had grown across the end of its petiole. This cork layer formed gradually during the autumn. When it was complete, it shut off all the sap tubes running from the twig into the veins of the leaf, with the result that the leaf withered and died. Then the cork was easily broken by the shaking of the leaf in the wind, and the leaf fell (Fig. 44). Could any sap leak out at the leaf scar?

Fig. 44. Buds of elm. Find the protecting scales, and the leaf scars covered with cork. Notice the spots on the leaf scar. Are these the ends of sap tubes?

Protection of the bud.—Now look at the bud to see whether it is well protected in preparation for winter. The bud does not feel the cold, but it does need to be prevented from drying out, for, during the cold weather, it cannot obtain water from the branch. Find the **bud scales** by which it is covered, and decide whether they appear to be waterproof. Some are covered with wax or varnish, and some with a furry coat. In either case, if they are dipped in water, they will come out looking quite dry. This shows that both of these coverings are waterproof. They therefore serve the double purpose of keeping in the sap and keeping out rain water that might carry disease germs or might freeze and injure the bud. The furry coat may be useful also in preventing the bud from being injured by too sudden changes of temperature, though it cannot keep the bud permanently warmer than the air around it. It may also prevent the bud from being eaten by insects or birds.

The forming of buds during the summer and the shedding of leaves in the autumn are preparations for winter. The question of how the tree will provide itself again with leaves

we shall not try to answer until the spring, when we can do so by watching trees or shrubs.

We have all seen or heard frequently of the store of food that is kept in some tree stems over winter ready to feed the buds when the spring comes. In maple trees this stored food is a sugary sap. People sometimes take some of the sap from sugar maples when it is moving upward to start the growth of the buds in the spring, and make it into maple syrup or maple sugar. In this way food that the plant stored over winter for its buds becomes food for people. Tapping does not seriously injure the maple tree, as only a small part of its sap runs out. Taste the sap that you see coming from Manitoba maples in the spring.

Question Outline

(1) To what dangers are plants exposed in the winter? (2) Why are the evergreen trees not broken down by snow? (3) How are their leaves protected against drying out? (4) Why does the sap not freeze and injure the trees as water bursts a pail when it freezes? (5) Why is an elm tree, with its "Y" branching, usually broken if a heavy snowstorm comes while it is in leaf? (6) When you find a rosette of leaves growing close to the ground in the autumn, what story can you tell of that plant's life history? (7) When will it ripen its seeds, and when will they begin to grow? (8) Why are plants of this kind likely to become bad weeds? (9) Why must broad-leaved trees shed their leaves? (10) What other preparation do they make for winter and for the following spring?

CHAPTER VII

HOW PLANTS PREPARE FOR THE HARDSHIPS OF WINTER (Continued)

Plants that shed their stems as well as their leaves.—1. *The herbaceous perennials.*—We have seen that the evergreens, with their needle-shaped leaves, do not need to prepare for winter; they are always ready. The broad-leaved trees prepare for winter by shedding their leaves and sealing up the scars with a layer of cork. What preparation is made for winter by such wild plants as the sow-thistles or golden-rods, and by cultivated plants such as peonies and tulips? They cannot shed their leaves and cover the scars with cork because they have no cork. Their stems are not woody; they are soft or "herbaceous." The plants cannot protect these soft stems against drying out and against frost in winter, and therefore the stems cannot be kept alive. Such plants prepare for winter by allowing their stems, as well as their leaves, to die and wither away. Only the root remains alive. The root lives for a number of years, and the plant is therefore called a **perennial** (*per*, through, *annus*, a year). The perennials that have woody stems (for example, the trees) are called *woody perennials*, and those with soft stems that die down to the ground each year are called *herbaceous perennials*. These are names much used in describing garden plants.

Dig up an herbaceous perennial, such as a sow-thistle, when it is in its winter condition (Fig. 45). You can see that its root is alive and unharmed by the frost. It will grow if you plant it. The herbaceous perennials retreat

into the ground for the winter as some animals do. Are they then well protected against the drying winds of winter? Are they in any danger of being broken by snow? Damage by frost is the chief harm that could come to them, and this is prevented by the gradual thickening of their sap.

How can the herbaceous perennials grow a new stem and new leaves in the spring? They have stored food in their roots, as the maples store food in their stems. When the warm weather comes, this food is used by the bud at the top of the root, which then grows to a new stem and new leaves. As soon as a few leaves have been formed, they help to manufacture more food to make other leaves and more stem.

Fig. 45. Herbaceous perennial in winter. The stem and leaves are withered, but the root is living over winter sheltered in the ground.

We have now shown clearly how woody perennials like the trees differ from the herbaceous perennials in their habits. A woody perennial, such as the young maple (Fig. 46), increases in size gradually from year to year and, after the first few years, produces seeds or helps to produce them every year. An herbaceous perennial, such as the aster (Fig. 47), dies down in the autumn and must start a new stem every spring. It can never reach a large size therefore, but it produces seeds every year. Look at the drawings and at the two kinds of perennials out-of-doors to see the differences in their life stories.

2. *The biennials.*—There are other plants besides the herbaceous perennials that retreat into the ground in preparation for winter. The carrot, beet, turnip, and parsnip are cultivated plants of this group. They store up a great deal of food in their roots during the first summer, but grow very little stem. The leaves grow directly on the top or crown of the thick, fleshy root, and, since no stems or flowers

are produced, nearly all the food made by the leaves during the first summer can be stored in the roots.

In the autumn the leaves die, but the root remains over winter with buds on its crown that are ready to grow rapidly the next spring. When spring comes, they send up a stem, that has leaves and also flowers that produce seeds. At

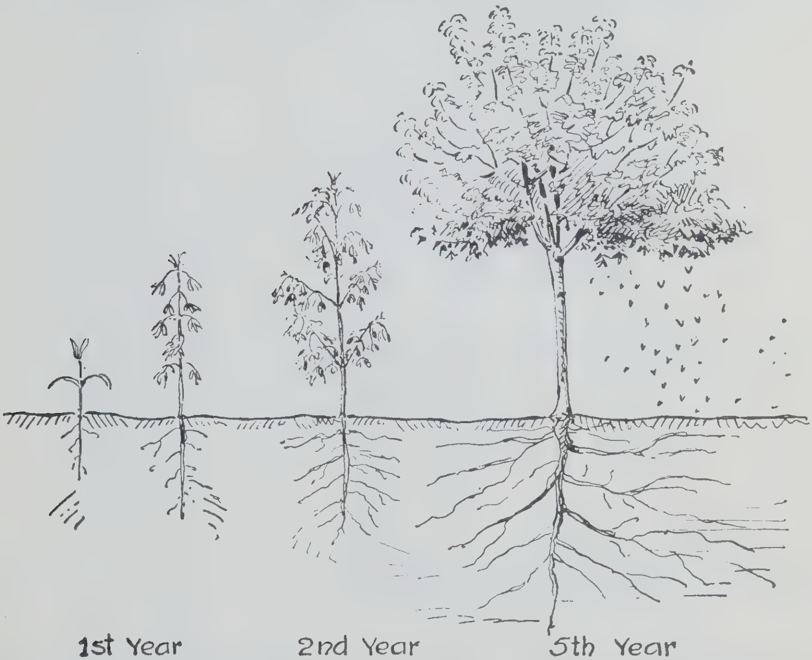


Fig. 46. The woody perennials, trees and shrubs, do not die down. They increase in size year by year and produce seeds each summer after they become "grown-up."

this stage they resemble herbaceous perennials. They produce so many seeds that they use up the entire store of food in the root, however, and when their seeds ripen in the autumn, the whole plant dies. Plants such as these, which live only two years, storing food in the first summer and making seeds in the second, are called **biennials.** Figure 48 shows the life history of a biennial plant. Study carefully how it differs from the perennial in Figure 47.

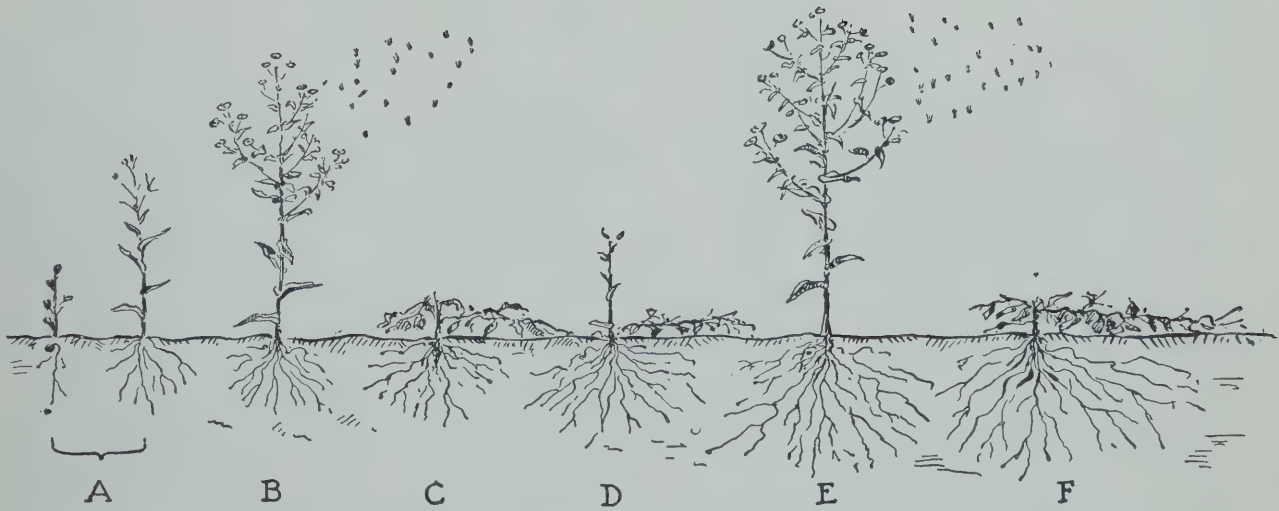


Fig. 47. These drawings show the life story of herbaceous perennials like asters, golden-rod, dandelion, thistles, and others. Study carefully what happens. A, The plant grows from seed. B, In the summer it produces flowers, and in the autumn seeds ripen and fly away. C, In the winter the stem and the leaves die, but the root lives on in the soil. D, In the spring a new stem comes up. E, The new stem produces leaves and flowers during the summer, and in the autumn more seeds ripen and scatter. F, In the winter the stem and leaves die, but the root lives on again ready to start a new stem the next year. The root becomes larger year by year, but the stem has to start afresh each spring, and therefore it does not grow large like those of trees and shrubs.

Most of our garden biennials have come to us from warmer climates, and their roots, if left in the ground, cannot withstand our winter frost. With us, they are usually dug up and used as food for people or animals, but in their native climates, if left in the ground, they would produce seed in their second summer. The radish and other biennials occasionally produce flowers and seeds towards the

Fig. 48. Biennials make food with their leaves during the first summer and store it in the roots over winter. In the second summer they use their entire store of food in making seeds, and then they die. Notice that the root is withered and shrunken at the end of the second summer. It is hollow from loss of food.

end of their first season. When this occurs, they use up their stored food and die.

Find radishes that have produced seeds. Examine their roots and see whether the stored food has been used up. Plant a carrot, parsnip, or other biennial root in a pot and watch it go through its second year's growth, producing flowers and seeds. The carrot will make an attractive fern-like house-plant. In the spring, plant a turnip in the garden and watch it flower and seed. The black-eyed Susan, some of the clovers, and the burdock are common

wild plants that are biennials. They do not store much food but are more hardy than the garden biennials, and are therefore able to survive our winters.

Plants that die completely—leaves, stems, and roots.—*The annuals.*—Some plants grow from seed, ripen their new seeds, and die, all within one growing season or in one year. These are called **annuals** (Fig. 49). In the autumn, an annual not only sheds its leaves and its stem, but the whole plant dies. Bring into the classroom a poppy plant that is dead but that has a seed pod with live seeds in it. It is an annual, depending entirely upon its seeds to produce plants the next year. Annuals make food and use it at once to produce seeds. In each seed there is a tiny living plant, and with it is stored a little "lunch," to be used when the plant wakes up in the spring. This is the only food that is stored over winter by annuals.

Fig. 49. Life story of an annual plant. It grows from seed in the spring, produces flowers in the summer and seeds in the autumn, then dies. Sweet pea and nasturtium are other annuals.

The season of growth of common annuals is the spring, summer, and autumn of the same year. The whole history of these annuals is short and simple, as is shown in Figure 49. Some very hardy annuals, such as the Frenchweed, we found (see page 32), begin to grow in the autumn, live throughout the winter in a rosette stage, or even in the flowering stage, and complete their growth and ripen their seed during the next spring. These are called **winter annuals.**

Question Outline

(1) What are herbaceous plants? What are woody plants? It is useful to remember that the woody plants are either trees or shrubs. (2) What becomes of the leaves and stems of herbaceous perennials in the autumn? (3) What part of these plants is perennial? (4) Why cannot their stems be kept alive through the winter? (5) How are the roots protected against drying out, and against other injury? (6) What preparation do the perennials make that enables them to produce new leaves in the spring? (7) The woody perennials grow larger year by year. Why cannot the herbaceous perennials ever become as large as trees? (8) What are biennials? (9) In how many seasons do they store up food? (10) What do they do in their second season? (11) What part of a common annual lives through the winter and grows again in the spring? (12) What are winter annuals?

Photo by L. W. Brownell.

Fig. 50. Dragon-fly, one of our insect friends.

PART II

AUTUMN STUDIES OF ANIMAL LIFE

CHAPTER VIII

INSECT FRIENDS AND ENEMIES

Insect friends of the flowers.—We have seen in our study of flowers that some of them have perfume, color, and nectar. From watching the insects that visit these flowers we learn that from a distance, they are attracted by the perfume, that when they come close, they are attracted by the bright color, and that when they alight in the flower, they secure nectar. Bees take home the nectar and make it into honey, which they store away in the honeycomb for winter food.

Is it not strange that plants have so many ways of being kind to insects and that they provide them with food? Some flowers, the pea for example, even provide landing stages or platforms upon which bees may conveniently alight. They provide food for insects and then guide them to the place where they may find it. Do the insects do anything for the flowers in return for so many favors? Do the insect visitors help the flowers in any way? Let us see.

When a bee alights upon a dandelion or sweet pea flower and searches for nectar, its hairy body becomes dusted with pollen from the stamens. Then, if it likes the nectar of that flower, it flies away to look for another flower that has the same perfume and the same color, where it may expect to find more of the same kind of nectar (Fig. 51). As it works about searching for nectar in the second flower, it dusts

some of the pollen from the first flower upon the pistil of the second. What difference does this make to the flower? We have seen (page 14) that, when the pistil receives pollen from another flower of its own kind, it is able to make good seeds. The insect is therefore doing useful work for the flower in bringing to it pollen from the other flower. The insect helps the plant to make good seeds, and the plant helps the insect to find food to store for the winter.

Fig. 51. Bumble-bee working in a flower. What is it doing? Of what use is it to the plant?

We see, then, that plants have good friends and helpers among the insects. These are the hairy-bodied flying insects, such as bees, moths, and butterflies, that carry pollen from flower to flower.

Insects that do not carry pollen. — Do you think that all insects are useful to flowers? Can you think of any kinds that would be of no use as pollen carriers? What about the insects that crawl but do not fly? Would insects such as beetles be of any use? Would pollen cling to their smooth, shiny bodies and wings? Since insects such as these are not able to carry pollen, they cannot help the flowers in any way. Might they even do them harm?

How do flowers prevent useless or harmful visitors from taking away the nectar that they have prepared for their useful friends, the bees and the butterflies? Look, for instance, at the nasturtium (Fig. 7). Its nectar is down at the bottom of a long narrow spur, where it can be reached only by those insects that have a long tongue, like the

butterflies (Fig. 80). The sweet pea flower has its nectar hidden in the tube between the stamens, and only a heavy insect, such as a bee, can open the keel of the corolla (Fig. 11) and uncover the stamens. Some plants, like the gumweed of the prairie (Fig. 52), have on the upper part of their stems a sticky substance which prevents crawling insects from climbing up to the flowers, and some plants are very hairy. In these and in other ways flowers keep out unwelcome visitors that might take nectar without carrying pollen. Flowers have a number of insect helpers, but they have also to guard against many unwelcome visitors.

Fig. 52. The gumweed has sticky, turned-down bracts or scales around its flower. Can this crawling insect secure the nectar?

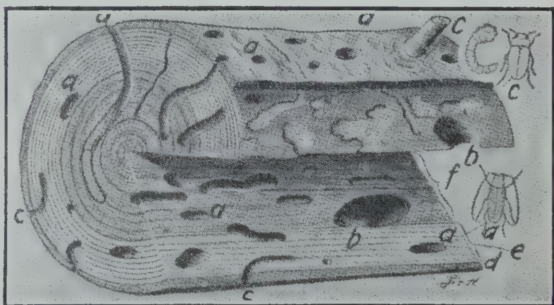
Insects that injure plants.—Some kinds of insects are unwelcome visitors not only because they might take nectar without carrying pollen, but also because they injure the leaves that make food for the plant, or even eat the whole plant. Caterpillars of moths and butterflies often devour the leaves of trees (Fig. 53). The cutworms that destroy grain crops and gardens are the caterpillars of night flying moths. Plant lice suck the sap from leaves and stems (Fig. 54). Potato beetles (Fig. 53) strip the leaves from the plant just when they are needed to

Fig. 53. Caterpillars and other biting insects eat the leaves, stems, or roots of plants.

manufacture food for storage in the new potatoes. Grasshoppers have changed the history of countries by destroying the crops and starving the people and animals. On the Canadian prairies they have more than once ruined the crops in large areas, where the people have been kept from starvation only by outside help.[1] The saw-fly and the wire-worm do enormous damage every year to the grain crops of Canada;

Courtesy Dept. of Agriculture, Ottawa.
Fig. 54. Plant lice (aphids) greatly magnified. These insects suck the sap of the plant.

and fruits, such as apples, are often the homes of very unpleasant intruders. Altogether, about one-tenth of all the crops raised in Canada each year are destroyed by insects. This is a tremendous loss, nearly a hundred million dollars a year. If we add to this the loss resulting from the damage done by insects to our forests, the total is more than one hundred and fifty million dollars. What is the average loss for each farmer who has a section of land? Is it worth while to protect the birds and to do our utmost in other ways to prevent the increase of harmful insects? If we had not the birds to help us, the insects would probably become so numerous that they would completely ruin our crops and forests. Try to imagine



Courtesy U. S. Dept. of Agriculture.
Fig. 55. Wood-boring insects injure trees and spoil the lumber made from them. The grubs of the beetle (*c*) make shallow holes. Those of (*a*) make deep holes.

[1]Read *Grasshopper Land* by Margaret Morley, Chapters XII-XV.

what it would be like if there were ten times as many insects everywhere as there are now.[1]

Find specimens of leaves or other parts of plants that have been damaged by insects and bring them to show the class. Look for pieces of wood or bark that have tunnels in them, made by wood-boring insects (Fig. 55). Bring into the classroom as many as possible of the insects that do the damage. In this way you may gradually build up a collection of the harmful insects of your district.[2]

There are some insects that injure plants in another way. They sting the stems or leaves, making small wounds in which they lay eggs. Into the wounds they inject a liquid that makes them heal in a peculiar way. They heal by making swellings that serve as houses for the grubs when they hatch out of the eggs. These interesting houses we call *galls*. You can find them very readily on stems of golden-rod (Fig. 3), rose, and willow. Some willow galls look like the cones of evergreen trees.

Collect some galls that have no holes in them. Open one of each kind, find the maggot or grub, and preserve it. Then place the remaining galls in small dry sealers, putting only one kind of gall in each sealer. Instead of the glass top, put over the sealer a piece of very fine net or muslin and screw on the metal ring. Examine the sealers occasionally, and when the insects are seen flying about in the jars, chloroform some of them and preserve them in liquid with the grubs. In this way you can mount the gall, the grub, and the full-grown insect. The insect is usually a tiny fly-like creature with two or four wings. It is difficult to understand how such delicate insects get out of their woody houses when they are ready. See if you can find that in some of the galls the grub has eaten a tunnel almost to the outside surface, and then gone to sleep. This leaves only a thin skin for the winged insect to push through when it is ready to emerge from its house.

[1]Read the poem *The Birds of Killingworth* by Longfellow.

[2]Insects are very easily preserved in thick glass test-tubes, shell vials, or small bottles in 3 per cent formalin solution (or 70 per cent methyl hydrate where there is danger of frost). Many kinds may be preserved dry. They may be killed humanely by placing them in a test-tube and adding two or three drops of chloroform. Gasoline will serve fairly well, but the body must be moistened with it to kill quickly, and the insect should be allowed to dry again before being placed in preservative. For directions for spreading moths, butterflies, and other insects to show their wings, see Appendix, Sec. 4.

Insects that are harmful to people and animals.—Plants are not the only living things that are attacked by insects. We know from experience that there are also insects which inflict injury upon people and animals. The house-fly, or "typhoid fly" as it is often called, is one of our worst enemies (see page 227). Mosquitoes also are harmful. In warmer climates mosquitoes carry diseases. In our climate they cause great discomfort to people and to animals, such discomfort that in some regions people can hardly endure them, and animals are so tormented that their growth is stunted (see page 217).

Some insects, such as lice and fleas, attach themselves to the bodies of animals, or people, and cause injury. Others live part of their lives inside the bodies of their hosts. Warble-flies live thus under the skins of cattle.[1] Insects that live on or in the bodies of living animals or plants and obtain their food from them are called **parasites.**

In addition to the insects which we have mentioned, there are some that do harm by destroying stored food. Meal-worms and larder beetles sometimes find their way into a pantry. Moths destroy clothing, carpets, and furs. Book-lice sometimes do great damage in large libraries by eating the leather and glue from the bindings of books. All of these insects are very destructive.

Find and preserve as many specimens as possible of our insect enemies, and of their destructive work.

After we have studied some particular insects, and have learned how they feed, breathe, and develop, we may be able to suggest ways of defending ourselves and our plants against their attacks.

[1]Examine the backs of cattle for lumps in which the grubs of warble-flies live. Besides injuring the animal when alive, they damage the leather made from the skins. More than 25 per cent of all hides tanned in Canada are thus injured.

Insects that are useful to people.—So many insects are harmful that we sometimes think of all insects as our enemies, and are inclined to crush under foot anything that crawls. This is a mistake. We have seen that a number of hairy-bodied flying insects are helpful to flowers in carrying pollen. They are helping us, also, when they pollinate the flowers that form useful fruits or seeds. Fruit crops can sometimes be more than doubled by placing a hive of bees in the garden. When red clover was first taken to Australia, it grew well, but it produced no seed until bumble-bees were also imported and set free in the fields. If we look about carefully and if we read what has been written about insects, we shall see that there are many insects that do much more good than harm.

When we recall the useful insects that we know, we probably think first of the honey-bees that make food for us. It is only in recent years that the people of the prairies have commenced keeping bees, but already the crop of honey produced each summer in Manitoba alone has grown to nearly 6,000,000 pounds. What is the value of this quantity of honey? Bee-keeping is increasing rapidly in the West, and our crop of honey will be larger. In Eastern Canada, and on the Pacific Coast, bees are kept in great numbers.[1] We shall learn more about the bee in our next chapter.

Another insect which makes something that we need is the silk-worm. This is not a real worm, but is the caterpillar of a moth. It lives on the leaves of mulberry trees, and would destroy them if it were out in the open where they grow. The caterpillars are kept indoors, and to feed them, a crop of mulberry trees is grown, as oats and hay are grown to feed horses. When they are ready to enter upon

[1]Write to the Publications Branch, Department of Agriculture, Ottawa, for the report showing the value of crops of wheat, fruit, and honey in Canada, and find in it how much honey, how much fruit, and how much wheat were produced in Canada last year.

their resting or pupa stage, the caterpillars spin silken cocoons, and it is from these that the silk is unwound to make silk thread and silk cloth.

Since mulberry trees do not grow in Canada, we cannot keep silk-worms, but from the spruce trees of our forests we make a silk-like substance, known as rayon, that is used instead of silk. A great deal of real silk, however, is still brought into Canada. Where is it produced?

Fig. 56. Caterpillar with cocoons of parasites. The larvae (grubs) fed inside the body of the caterpillar until they killed it. Then they came out and made cocoons. When the flies hatch out, they will lay eggs on other caterpillars.

The honey-bee and the silk-worm make materials that we can use for food and clothing. Can you think of any other ways in which insects are of use to us? Have you seen dragon-flies, which are often called "mosquito - hawks," hunting about for food? If you can catch one, feed it with flies. Do you think it does any good? Dragon-flies and many other species that feed upon smaller insects do much to limit the numbers of harmful insects. The lady-beetles feed upon scale insects[1] and potato beetles; the hover-flies and lacewings feed upon aphids or plant-lice (Figs. 54, 81, and 82). Many kinds of beetles are useful, some because they feed upon other insects and some because they eat or bury dead bodies of small animals and birds. Some kinds of wasps feed their young upon harmful insects—caterpillars, cut-worms, flies, etc., and therefore even wasps are our friends.

In addition to these helpful kinds of insects, there are also some useful parasitic insects. Have you seen a caterpillar, or rather the dead shell of a caterpillar, with little

[1]When scale insects had nearly destroyed the orange groves in California, lady-beetles were brought in from Australia. They killed off the scale insects so that the orange trees again produced good crops.

white cocoons standing upon it, as shown in Figure 56? A fly laid its eggs on the caterpillar, and the grubs lived in the caterpillar's body, until at last they killed it. Then they formed cocoons outside its body, and from these, when fully grown, the flies hatched. Grasshoppers and many other harmful insects are killed by parasites in this way. These parasites are therefore very useful to us.

Question Outline

(1) What work is done by insects that benefits flowers? (2) What kinds of insects are able to do this work? (3) What do insects receive in return for their work? (4) In what ways do insects harm plants? (5) What are galls? How do the insects escape from them? (6) Name insects which you have seen that are harmful to people or animals. (7) What kinds of insects are useful to people?

CHAPTER IX

THE HONEY-BEE[1]

Further questions about insects.—In collecting specimens of useful and harmful insects you have doubtless noticed some things about them. Some have large wings, some have small wings; some have bright colors, and some are dull. Some are hairy, while others are smooth and shiny.

Have you looked at any of the insects closely enough to see how many legs and wings they have, or how they climb up the stalk of a plant? Are their legs joined all along their sides? Have they fingers and toes? How many eyes have they? Have they ears? Can they smell?

How may we safely question a bee?—If a living honey-bee or bumble-bee is watched for some time, its actions will tell us many things. If there is an apiary in your neighborhood, the bees will be found in every flower-garden and on every lawn where there are dandelions.[2] If not, bumble-bees may occasionally be found, especially on clover heads. These bees are easily kept for a few days. Dig up some turf with clover flowers on it, and fit it into the bottom of a sealer that has a screen cover.[3] If you cannot find clover, use grass turf to hold the moisture, and put in the jar with it other nectar-bearing flowers, such as dandelions, or feed the bees on drops of syrup. The cages described in Chapter X for grasshoppers may be used, but care must be taken to avoid receiving a sting through the netting.

[1]The study of the grasshopper in Chapter X is alternative to this chapter. One or other may be omitted without detriment to the general study of insects.

[2]To capture a bee on a flower, cautiously enclose it between a fruit sealer, held in one hand, and its glass cover, held in the other. Move slowly, and the bee will not become angry.

[3]For this type of cage see Figure 68, page 70. Miss Margaret Morley, author of *The Honey-Makers* (McClurg & Co.), says of the bumble-bee: "Its large size and good nature make it a pleasant home companion," but in a classroom *bombus* would perhaps be safer if kept in a cage or a jar with a screen top. If an observation hive can be set up in the science room window, we may visit the bees in their own home. For instructions regarding observation hives, see *Nature Study and Life* by C. F. Hodge (Ginn & Co.).

Some of the questions that we asked about insects we might answer after watching the captive bee. In fact, if enough living bees in sealers or tumblers with secure screen covers can be provided for each member of the class to watch their actions closely, we shall find answers to nearly all our questions without seeking further. If enough living insects are not available, preserved specimens may be used, though they are much less interesting. Some of each kind should be provided, so that what cannot be seen by observing one may be discovered by observing the other.

The three divisions of the body.—Now let us look carefully at the bee (Fig. 57). Looking down on the back of the insect, notice the shape of its three body parts. At the front is the rather flattened **head.** It is joined by a very thin neck to the chest region, or **thorax.** To the other end of the thorax is joined, by a thin "waist," the **abdomen.** These three divisions make up the body of the insect. Our own bodies have the same three parts, but in them the thorax and the abdomen are more closely joined together than in the bee.

Fig. 57. Honey-bee. Notice the three divisions,—head, thorax, and abdomen. What parts are attached to each?

Make an outline drawing of the bee's body as you see it when you look straight down on its back. This drawing should be about twice natural size.[1]

Parts attached to the head.—If we look at the front of the bee's head (Fig. 59), we shall notice first the two feelers, or **antennae,** attached near the middle of the "face." You have only to watch the living bee to answer, in part at least, the question "Of what use to the bee are the antennae?" When the bee alights on a flower, it first feels about with its antennae, evidently searching for nectar and pollen. Notice how swiftly and lightly these feelers touch each part of the

[1]For suggestions on the preparation of diagrams see specimen page of note-book, page 11.

flower. They are very sensitive to touch, to smell, and to sound. With its antennae the bee smells the perfume of flowers and hears the various sounds about it. With them it also seems to "speak" or signal to its friends. Since the antennae serve as hands, nose, and ears to the bee, they are very important parts, and serious injury to them leaves the bee almost helpless.

On the sides of the face you will be able to see the two great shining **compound eyes,** each made up of tiny sections, or *facets*, fitted together like the cells of a honeycomb (Fig. 58). There are about six thousand of these little sections in each eye. You cannot easily see these little sections of a bee's eye without a microscope, but on the larger eye of a dragon-fly you can see them with a good magnifying glass. With its compound eyes the bee sees patches or fields of flowers in the distance, and finds its way on its foraging journeys. These eyes do not, however, see clearly the things that are nearby. The hairs that grow out between the facets help to protect the eye and probably also help the bee to feel about in the darkness of the hive. Did it ever occur to you that bees do their wonderful work of building a honeycomb, storing honey, and bringing up their young in a home (hive) that is without windows and has only one very small door? (See Fig. 62.)

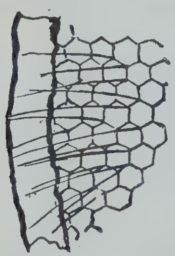


Fig. 58. A small part of the surface of the compound eye of the bee. How large would the drawing have been if all of the facets had been shown?

Besides the two large compound eyes, the bee has on the top of its head three **simple eyes,** which are very small and almost covered with hairs (Fig. 59). With the aid of a magnifying glass these can readily be found on the head of a bumble-bee. With these eyes the bee sees objects that are close at hand. Even in a crowded apiary of many hives, bees find their own doorstep apparently without difficulty.

The antennae and the two sets of eyes help the bee in its search for the flowers that contain nectar, and enable it to find its way home after it has filled its crop with a drop of the fragrant liquid.

But how does the bee obtain nectar from the flower? If you watch a bee working in a flower, you will see it push out a long tongue. In a preserved specimen the tongue may be seen folded under the throat. In Figure 59 the tongue is shown partly extended. When fully extended, it reaches out more than half the length of the body. Notice the tiny spoon on the end of the furry part. With this the bee laps the nectar and sucks it up through the tube-like part above into its nectar crop. In addition to the tongue with its two covering sheaths, the bee has also a pair of short curved jaws. The jaws are opened wide when the tongue is extended. With these the bee builds the delicate honeycomb of wax. These parts are shown in the diagram.

Fig 59. Bee's face, showing clearly antennae, compound eyes, simple eyes, and jaws. The tongue is extended to the position for taking nectar from a flower.

Parts attached to the thorax.—After the bee has found the flower and filled its honey crop, how does it carry its treasure home? You have already seen, no doubt, that for carrying itself and its loads the bee has **wings** and **legs.** These are attached to the thorax, or middle division of the body. Observe the wings and legs on the living insect and find how many of each there are. Does the thorax appear to be a strong, sturdy part of the body? Is it covered with hairs? Look again at Figure 57.

The wings of the bee are small to carry so large a body, but they are very strong. How many wings do you find? Which pair is the larger? Can you see through them? They have a strong framework of veins that keeps them stiff so that they carry their load without bending. When the bee is flying, do the wings seem to work more rapidly than those of a butterfly?

The wings of the bee are stronger than those of other insects of their size partly because they can be joined together in such a way that the two wings on the right side work as one and the two on the left as one (Fig. 60). As soon as the wings are raised into the flying position, a row of tiny hooks on the front edge of the hind wing slips into a groove on the rear edge of the larger fore-wing and holds the wings firmly together as long as they are held outstretched. On a specimen the wings may easily be hooked together and unhooked again, even though the separate hooks cannot be seen.

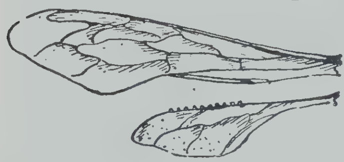


Fig. 60. The two left wings of the bee. Notice the tiny hooks and the groove into which they fit. Of what use are they? You can fasten and unfasten them on a preserved specimen.

Spread the wings of a specimen and add them to the drawing that you made of the three divisions of the body. Notice how well the hind wing is covered and protected by the fore-wing when they lie together along the bee's back.

The legs of the bee are nearly as important and even more interesting than its wings. Notice that they are all attached to the thorax and quite close together. How many pairs do you find? When you see a bee climbing about on a flower, does it seem to have strong legs? Are the bee's legs smooth or hairy?

Watch the insect when it is in a flower, especially in a poppy or a rose that has much pollen but no nectar, or on mignonette that has bright orange pollen. Does the bee

become dusty with pollen? Find, if you can, in one of these flowers a bee that has collected a little ball of pollen on the outside of each hind leg.

Look carefully at every bee that you see in a flower until you see these little "baskets" (shown at *pb* in Figure 61), on the *hind* legs filled with pollen. This pollen the bee has collected from its hairy body. With little combs on the right hind leg it fills the basket on the left hind leg, and with those on the left it fills the basket on the right. It carries these baskets of pollen home for food, but enough pollen remains on its body to pollinate the flowers, which, therefore, are not robbed of the pollen that they need. On each hind leg there is also a pair of wax pincers with which scales of wax are cut off when they are formed on the under side of the abdomen.

Fig. 61. The three right legs of the bee. Notice the pollen basket (*pb*) on the hind leg, and just below it the wax pincers (*wp*). Below this on the inner side of the leg are pollen combs not visible here. The middle leg has a spur (*s*) with which pollen is removed from the baskets. On the front leg notice the semi-circular comb (*ac*) for cleaning dust off the antennae, and the brushes for cleaning the eyes (*eb*) and other parts. Try to find these parts with a magnifying glass.

Each leg of the *middle* pair has a little spike or spur with which the pollen is dug out of the baskets when the bee arrives at the hive, and each *front* leg is provided with a little semicircular comb for removing pollen or other dust from the antennae. Why must the antennae be kept very clean? Bees are among the cleanest of living things. By breathing upon a captive bee, or dusting it with a little flour, you may set it to work "cleaning up." These parts on the legs are too small to be seen without a very good magnifying glass, but it is interesting to know that they are there, and you may find an opportunity later to see them.

All of the legs have brushes or combs or both brushes and combs for removing pollen and other substances from every part of the body. The feet of the bee you can see when the bee is climbing up a glass wall. They are somewhat like those of flies, consisting of two claws separated by a sticky pad. The pad is used only when walking on a very smooth surface.

Parts attached to the abdomen.—The third division of the body, the abdomen, is very different from the head and the thorax. You drew its outline at the beginning of your examination of the body parts of the bee. Now look at it more closely. Can you see that it is made up of rings, or **segments**, somewhat like those of the body of a caterpillar? How many of these segments are there? Mark them in your drawing of the back view of the bee. Is the abdomen hairy enough to carry pollen from flower to flower? In the living insect can the abdomen move or bend? Each segment is fairly hard, but the joints between them are made of soft skin, which permits movement. The covering of the abdomen is somewhat like the armor worn by the knights of olden days, but it has hairs upon it.

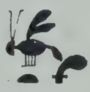
There is one part attached to the abdomen which may be seen on a preserved specimen, but which it would be risky to attempt to find on a live bee. This is the **sting.** It is found at the tip of the abdomen and, in preserved specimens, is usually extended. It is a tiny weapon like a fine double needle, with backward-pointing barbs. It serves the bee as a poisoned dart with which to attack the enemies of the bee colony. It makes only a tiny wound, but injects into it a very powerful poison that immediately causes much pain and swelling. One angry bee alone is an enemy to be feared, but a swarm, if thoroughly aroused, is really dangerous. People and animals, including horses, have been stung to death by bees. Many stories are told of the use of bees for defence or attack. At the siege of Tanly the breaches in the walls are said to have been defended against the Spaniards by a few hives of bees. Bees have also been known to drive people out of towns and villages. Why does the bee need such a deadly weapon? Without it could wild bees defend their winter's store of food against the ravages of animals? What would happen if they lost it?

Sometimes the bee strikes very lightly with its sting, inflicting a painful wound but not injuring itself. Frequently, however, the sting is driven more deeply into the skin and is held fast in the wound by the barbs. It is then torn from the bee's body, and as a result the bee dies. The sting, which is thus left in the wound, has at the top a little poison sac. If the sac is grasped by the fingers to pull the sting out, the poison is squeezed into the wound. If it is scraped off with a needle or knife-blade, the poisoning will be much less severe.

Watch the living bee to see if you can detect any breathing movements in the abdomen. Along the sides of the abdomen are tiny holes called **spiracles**, or breathing pores (*spiro*, I breathe). These are the outer ends of tubes that branch in all directions carrying air to every part of the body. Some of them branch even into the veins of the wings. The spiracles are difficult to find in the bee on account of the hairiness of the body, but we shall see them later in other insects (Fig. 76).

On the upper side of the abdomen the joints between the segments can be clearly seen. On the under side the plates overlap, covering the soft skin of the joints. Where this occurs there are little hollows called **wax pockets,** in which wax is produced. Scales of wax push out past the edges of the abdominal plates, and are cut off by the wax pincers on the hind legs. The wax is taken into the mouth and mixed with saliva, and is then built into the honeycomb by the jaws. Some of the bees in the hive are given the special work of eating large amounts of honey and making it into wax, but all of the worker bees help to make the wax that is required.

The life story and work of the bees.—The common expression "as busy as a bee" is a reminder of the good reputation that the bees have earned by their industrious habits, and there is no doubt that they well deserve all the good that is spoken of them. They have been known since the beginning of history as very hard-working, clean, and

useful little servants of man. In many of the poems and religious writings of ancient India, Egypt, Greece, and Rome, as well as in the Bible, the bees and their honey are given high praise.[1] In Egyptian hieroglyphics, or picture writings, the title of the keeper of the king's treasury was written thus:  and the title of the king himself contained the picture of a bee to indicate the part of the country over which he ruled. The bees that you have seen in the flowers and the bees that we have described are **worker bees.** We shall now learn something of the other members of the bee family and of their doings in the hive.

Courtesy Dept. of Agriculture, Winnipeg.

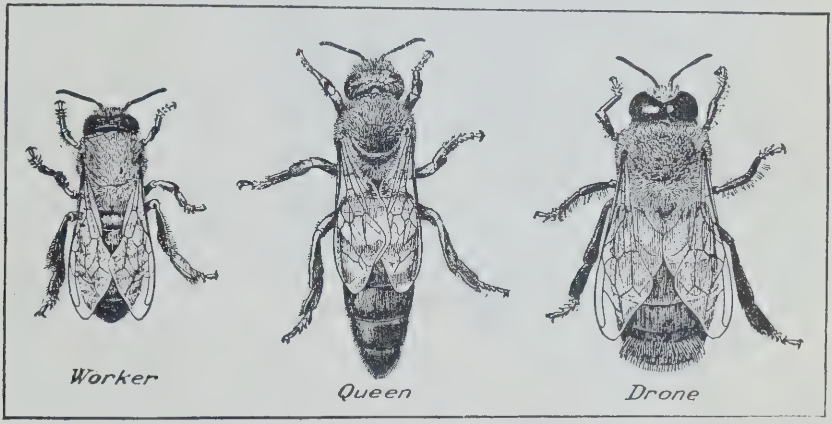
Fig. 62. A Manitoba apiary. Notice the box-like shape of the hives. Small sections of comb are placed in the upper sections, and these are removed after the bees have filled them. The inset shows an old-fashioned straw hive.

The bee family.—In one family or colony of bees that live in one hive, there may be from fifty thousand to one hundred thousand bees. This is a great multitude. Only on rare occasions does a crowd of one hundred thousand people assemble, but vast numbers of bees live together all season in one small house (Fig. 62).

In this great family of bees there is one mother-bee, who is called the **queen** (Fig. 63). She does not act as a ruler of the hive, but she is waited upon and fed and protected by a great company of servants and nurses. They feed her upon digested food from their mouths (royal jelly), and take

[1]For numerous and interesting references see *The Honey-Makers* by Margaret Morley (McClurg & Co.).

great care to protect her from all harm. She has only one task to perform,—the laying of eggs, which will hatch and make the bees in the colony more and more numerous. It is a calamity for the colony if the queen is lost. Notice in the diagram, or on a specimen of a queen bee, that the abdomen is very large. Within it are the ovaries, which produce enormous numbers of eggs. You will remember that the ovary of the pistil of a flower produces ovules that



Courtesy U. S. Bureau of Entomology.

Fig. 63. The three kinds of bees in the colony. How many of each kind are there in one hive?

grow into young plants. In a similar way the ovaries of the queen bee produce eggs that very soon grow into young bees.

There is in the hive, also, a small group of male bees called **drones.** The drones may number from less than one hundred to many hundreds. One of them provides the queen with sperm cells with which to fertilize some of the eggs, as pollen from a stamen fertilizes the ovules in the pistil, enabling them to grow into seeds.

All the bees in the hive, other than the queen and the drones, are female **worker bees.** There are many thousands of these. They do not lay eggs. We shall now see how the work is carried on in the hive.

Stages in the life history of bees.—At the beginning of the season the worker bees build wax cells that look like honeycomb cells but are a little smaller. These form the brood comb, or hatching comb (Fig. 64). Like the ordinary honeycomb, it is suspended from the roof of the hive by one edge, so that the cells are in a horizontal position, as shown in Figure 65. Each of the cells is six-sided, so that they fit together perfectly without waste space and without sharp corners. Notice the wonderfully regular pattern shown in the figure or in a piece of honeycomb. The bottom of each cell fits between three other cells, so that it is greatly strengthened.[1] So delicately and yet so strongly are the cells moulded that one pound of beeswax makes sufficient comb to hold thirty pounds of honey.

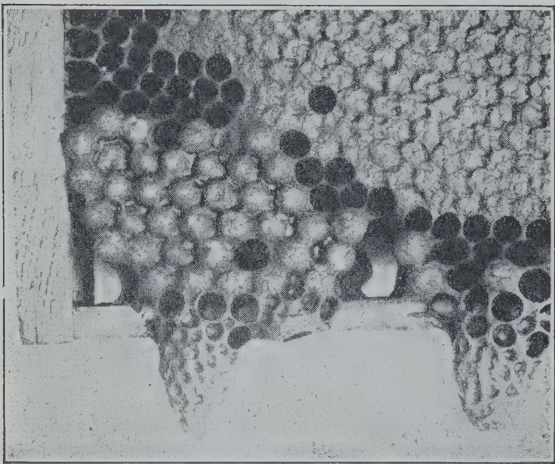


Fig. 64. Brood comb, showing queen cells, drone cells, and worker cells.

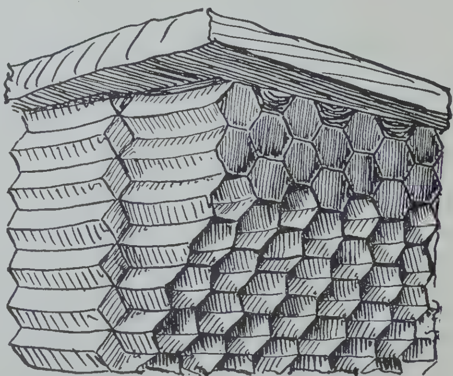


Fig 65. Honeycomb hanging by one edge from roof of hive.

When a group of brood comb cells has been built,

[1]To see this wonderful workmanship, cut away a piece of honeycomb until the cells are very shallow; then wash out the honey with cold water and pour in thin plaster of Paris, over-filling the cells. After it has set, remove the wax.

the queen bee walks over them. As she comes to each cell, she thrusts her head into it, as if to inspect it, and then deposits in it a fertilized egg (Fig. 66). The queen bee may lay as many as three thousand fertilized eggs each day during several weeks in the summer. In addition to the ordinary brood comb cells, the hive also contains larger brood cells, about the size of the honeycomb cells, and in these the queen lays unfertilized eggs.

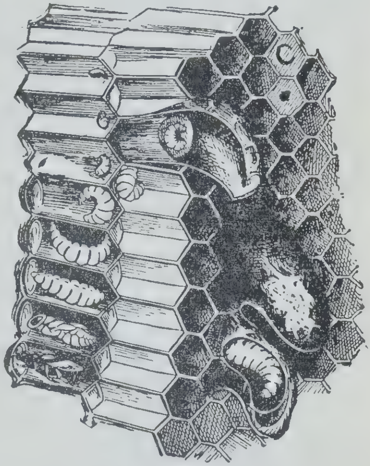


Fig. 66. Brood comb opened to show stages in life history of bee. Find the egg, the growing larvae or grubs, and the pupa. At the bottom see the adult ready to come out of the cell. The very large cells contain queen larvae.

While the brood combs are being built and the eggs placed in them, the surrounding cells are filled with a mixture of pollen and honey called "bee bread." This is the store of food to be used by the young bees when they hatch.

After about three days each **egg** hatches, and a tiny worm-like maggot, the **larva,** comes out. These larvae are cared for and fed by worker bees who act as nurses. For the first three days all the larvae are fed upon digested food from the nurses' mouths, and from the fourth day some of them are fed upon bee bread. The larvae are all much alike in appearance, but those from the unfertilized eggs grow up to be drones, while those from the fertilized eggs grow, with ordinary feeding, to be worker bees. By special feeding the nurse bees may cause any worker larva to grow into a new queen. By this method a successor is provided when, by accident, the queen of the hive is lost.

The larvae that are to grow up to be drones and new queens are fed upon the royal jelly from the mouths of the

nurse bees all through their feeding time, until they are ready to change to the pupa stage. This is less than a week altogether.

When the larva has grown so large that it nearly fills the cell, the nurse bees close it in with a cover of wax and bee bread, through which air can circulate, and leave it to rest. It is then in the **pupa** stage. While resting in this stage, the worm-like larva develops wings, legs, antennae, eyes, and all the other parts that we found in the adult or grown-up bee. This change from maggot to bee takes from one to two weeks. At the end of that time the young bee bites through the cover of the cell and comes out a full-grown **adult** bee.

When a worker bee comes out of the cell, she sets to work at once as a nurse bee, looking after her newly hatched sisters, serving the queen, cleaning the hive, and doing other housework for a period of about two weeks. Then she is ready to fly out in the sunshine to collect nectar and pollen from the flowers. It is these older, grown-up worker bees out in search of nectar that we see flying about or working in the flowers. In the busy part of the honey season, the worker bees toil so hard that at the end of six or eight weeks they are worn out and die. Those that are hatched late in the season live through the winter and care for the first larvae of the next summer. Then they die, also. Only the queen lives more than one season.

When a new queen is hatched, the old queen is very much disturbed. She will not share her kingdom with another queen, and often kills her rival by stinging her. If the hive is crowded, however, the old queen gathers together a large number of her faithful followers and leads them off in a swarm to find a new home. When a queen comes out of a hive, she alights on a tree or other convenient place, and her followers form a dense mass about her, clinging to one

another by thousands (Fig. 67). At this stage, bees may be placed in a new hive without difficulty. If they are not hived, they will fly off in search of a new home and be lost. After the departure of the old queen, the new queen is in possession of the hive. She has with her some workers and drones, and has before her the task of laying more eggs to build up the colony to its full number again. There must be a great number of workers to lay by a plentiful supply of honey for the winter. If a colony swarms late in the season, it often fails to grow large enough again before autumn to provide the necessary store of food and therefore cannot survive the winter.

Photo by Dorothy Smith.

Fig. 67. Swarm of bees collected on a branch after leaving the hive. Notice the hand of the beekeeper who is carrying them to a new hive.

When the drones hatch out of the eggs and complete their larva and pupa stages, they live in the hive or fly about outside in complete idleness. They cannot collect nectar or pollen and do none of the regular work of the hive. They live partly on the honey that the workers have stored, and for the rest of their food, as they cannot digest pollen, they depend upon their worker sisters. The workers feed them, apparently quite willingly, upon digested food like that prepared for the larvae. It is not difficult to understand why it has become customary to speak of lazy people as "drones."

The drones appear to be useless in the colony, but, as we learned earlier, one drone is needed to provide sperm cells to fertilize the eggs. Towards the end of the season, when winter stores must be saved, all the drones living in the hive are driven out or stung to death, as the workers refuse to continue feeding them all through the winter.

Can we learn any lessons for ourselves from the great bee family that lives in the hive? Are the bees selfish? Do they work for one another? Does each worker store honey for herself? Whose is the honey store? Do the workers learn to do their work skilfully? Do they leave it unfinished or untidy? Do they make mistakes or make honey of a poor quality that will spoil? Suppose that just one generation of young bees in a hive became careless or selfish and did not do its share, what would become of the whole colony in the following winter?

At the beginning of our observations of bees, we watched them working in flowers and examined specimens to see what we could for ourselves. We have also learned some things about bees that other observers have discovered after many years of careful study, and therefore we now know much of the bees' story. Yet there are many other interesting things that bee-keepers could tell us of bees and their work. Therefore, if you know of someone who has a hive of bees, ask about them. Find out from what flowers the bees collect nectar, how often they swarm, where they are kept during the winter, how much honey they collect each year, and other interesting information.

By studying the bee carefully we have also learned many things about other insects. What we have learned about the body of the bee and about the parts attached to its head, thorax, and abdomen will help us to understand other insects.

Question Outline

(1) How many main divisions are found in the body of the bee? What are they? (2) Of what importance is the hairy covering of the body of the

bee? (3) What parts are attached to the head? (4) What uses have the antennae of the insect? (5) What two kinds of eyes has the bee, and how many of each? (6) Where are the compound eyes? (7) How does the bee find the flowers that have nectar? (8) How does it take the nectar from the flower, and in what vessel does it carry it home? (9) What use do bees make of the nectar that they collect? (10) What parts are attached to the thorax? (11) How many wings are there? (12) How do they compare in size with one another and with those of other insects? (13) What special structures on the wings make the bee a strong flier? (14) What are the "veins" of the wings? (15) How many pairs of legs has the bee? (16) What are the little yellow knobs often seen on the outside of the third pair of legs of the bee? (17) Where does the bee collect this material? (18) What are the uses of the numerous brushes and combs which the bee carries? (19) What other special devices are found on the legs of the bee? (20) How is the abdomen able to bend or change in length? (21) Where is the sting? (22) Why is the wound made by it so painful? (23) Does the bee die after stinging? (24) How should a sting be removed? (25) How does the bee breathe? (26) Where is beeswax produced? (27) How does the bee mould the wax into the form of the honeycomb? (28) How do the three kinds of bees in the hive differ from one another? (29) What share of the work is taken by the queen, the drones, the workers? (30) Tell what you know about the brood comb, royal jelly, bee bread, swarming. (31) What stages does the bee pass through in its life history? (32) What does it do in the larva stage and in the pupa stage?

CHAPTER X

THE GRASSHOPPER[1]

Preparation.—In any dry summer season on the prairies grasshoppers are so plentiful that specimens may be found without difficulty. Almost any kind is satisfactory for purposes of observation, but the smaller specimens are likely to be only partly developed. Bring into the classroom some small specimens without wings, as well as some full-grown ones, and preserve them for later use. If possible, include in the collection some specimens as small as grains of wheat. Any that have complete wings are full-grown, even though they may be small in size. A number of live specimens should be kept

Fig. 68. Insect cage, fruit-jar style. The cover is made of screen.

Fig. 69. "Tomato can" cage with can cut to shallow form.

Fig. 70. Pudding-dish size, suitable for caterpillars feeding upon plants, etc.

for a few days in cages (Figs. 68, 69, and 70) where they may be easily observed. Large specimens preserved in methyl hydrate or formalin should also be available.

Simple and effective cages may be made from black mosquito screen as indicated in the Appendix, Sec. 3. Follow the instructions given there and make enough cages so that each member of the class may observe one closely. These cages will form comfortable temporary homes for many kinds of insects.

What questions will the grasshopper answer?—Having secured some specimens, let us see what we may learn from them. Like the flowers and the bees, they cannot tell us about themselves in words, but if we watch them carefully, we may see what they have to show us.

[1]This chapter is optional if Chapter IX has been studied.

The legs and the wings.—The most noticeable parts of the grasshopper, as it clings to the grass or crawls up the side of the cage, are its **legs.** How many are there? It can walk and climb, but can you imagine a grasshopper trying to run? When you were catching your specimens, did they use their legs in other ways? Would hopping enable the grasshopper to escape from birds or other enemies? Which legs does it use when it hops? Notice the feet, especially the hind pair. Can you see the spikes on the heels? Would these prevent the grasshopper from slipping when it suddenly hurls itself forward by straightening its hind legs? Place a grasshopper on a very smooth, hard surface, a piece of glass for example, and see how far it can jump. How do you account for the result? Does it ever escape or defend itself by kicking? Notice how well the spines and the claws at the end of the foot are fitted for grasping. Observe how the grasshopper clings to a blade of grass. Can you think of any way in which the spines down the back of the leg would be useful? The thighs of these jumping legs are enormous compared with those of the other legs; this is because the muscles that are used for hopping and kicking are attached there (Fig. 71).

Fig. 71. Jumping leg of grasshopper. Notice the great thigh, in which are the muscles. Are the spikes on the "heel" useful in making the spring? Notice also the toe claws.

Its legs, with which it walks and hops, are not the grasshopper's only means of moving about. It has also two pairs of **wings.** Can you see any difference between the front pair and the hind pair (Fig. 72)? Fully spread the wings of a large freshly-chloroformed specimen, or of one that has been preserved, and see how the two pairs of wings differ. Mount a specimen for your school collection.[1] The

[1]For suggestions see Appendix, Sec. 4.

front wings are used more for protection than for flying. Notice how the large, delicate hind wings fold up like a fan. Watch a grasshopper flying out-of-doors. Can it fly far? Can it turn to the left or right while it is flying, as do birds, bees, and flies? Watch the grasshopper when it alights after flying. Does it skilfully perch on a grass stem, as a bird perches on a branch, or does it tumble into the grass and then scramble to its feet again? Perhaps it is at such a time as this that the spines on the backs of the legs are useful. When it alights in this clumsy fashion in the rough grass, its delicate hind wings would often be damaged if they were not well protected. Many other insects, especially the beetles, also have hard fore-wings, which protect the more delicate flying wings. The hard shell of a beetle's back is formed by the two wing covers fitted together.

Fig. 72. Grasshopper flying. Notice that the front wings are held outstretched, like the wings of an aeroplane, while the hind wings move.

In trying to capture your specimen, especially if it is a Carolina locust with bright red or yellow wings, perhaps you noticed another advantage in the dull brown wing covers, an advantage to the locust, but a decided disadvantage to the hunter. When flying, the color shows brightly, but the moment the wings close, the whole insect changes to the gray or brown color of the soil. The grasshopper seems to know that to avoid being seen it has only to remain motionless. Have you seen other insects remain motionless, as though pretending that they were dead, until a danger that threatens them is passed?

The three divisions of the body.—While the grasshopper is crawling up the inside of the cage, the under side of the body can easily be examined (Fig. 73). Notice the **head.** It is very short but is as broad as the body. On the under side of the head the mouth parts are plainly seen.

Notice the middle division of the body. It is very thick and strong, being protected and held in shape by the hard, shiny breast-plates and the large saddle-shaped plate over the back. This division of the body is called the **thorax,** or chest region. To it are attached the four wings and the six legs which carry the body. Does the thorax need to be strong?[1]

Fig. 73. Under surface of body of grasshopper. Notice the three divisions of the body: head, thorax, and abdomen. Notice also the joints between the plates covering the body.

The third section of the body, the **abdomen,** is longer, softer, and more flexible than the thorax. Does it remind you of the body of a caterpillar or of a worm? Notice that it is made up of rings or *segments*, and that each ring has an upper plate and a lower plate, the two being joined along the sides.

Parts attached to the head.—Now that we have seen the three divisions of the grasshopper's body, let us look more closely at each division, beginning with the head. You will notice first the **antennae** (Fig. 74) and the large, shiny eyes.

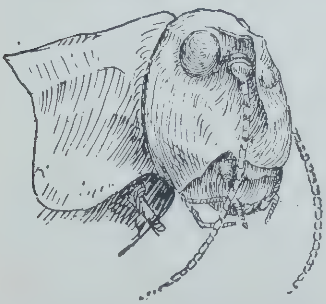


Fig. 74. Grasshopper's head. Notice the eyes, antennae, lips, and palps.

Watch your specimen in the cage to see for what purpose it uses its antennae. Does it use them to investigate its surround-

[1]The very strong framework to which the engine, wings, and undercarriage of an aeroplane are fastened corresponds to the thorax of an insect.

ings? You will quickly discover that the antennae are used as feelers. They are also the organs of smell. All along the antennae are tiny "smell-hollows," sometimes as many as fifty on each little jointed section. Can you see the sections? Some insects, the bee for example, also hear with their antennae (see page 56), but the grasshopper has other ears. According to the length of their antennae, the grasshoppers are divided into two great families, the short-horned group being the locusts, and the long-horned group the meadow grasshoppers, katydids, and others.

The two great **compound eyes** are very prominent on the sides of the head. Each of them consists of several thousand little shiny sections or *facets* that fit together like the cells of a honeycomb (Fig. 75). You may see these eyes with a good magnifying glass, better perhaps on a preserved specimen which may be held motionless in a very good light. Look for the compound eyes on other insects; the dragon-fly has unusually large ones. Besides the two large compound eyes, the grasshopper has three **simple eyes,** one in a vertical groove in the middle of the face and one above the base of each antenna. In some specimens these may readily be seen with a magnifying glass, but in others they are difficult to see. Try to find at least the middle eye.

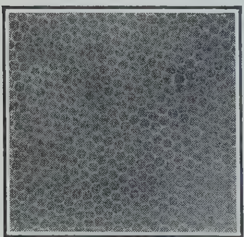


Fig. 75. Photograph (taken through a microscope) of part of the surface of an insect's eye.

Grasshoppers, like many other insects, are very short-sighted. The simple eyes apparently see clearly only to a distance of a few inches, and the compound eyes cannot detect even large moving objects more than a few yards away.

When we viewed the grasshopper from the under side, we noticed the mouth on the lower side of the flattened head. It is difficult to see the mouth parts unless you can

induce the insect to use them. If it is kept in a cage without food for a day and then presented with the tip of a blade of grass, it may begin to eat. Sometimes, also, when a grasshopper is being caught, it produces from its mouth a drop of tobacco-colored liquid that is probably distasteful to the bird which is attempting to capture it. During either of these processes, the **jaws** may sometimes be seen working. The jaws work sideways, instead of up and down as ours do. Beside them you will readily see two pairs of jointed food-feelers, the **palps.** There are also other mouth parts that help to bring the food into the mouth. Enclosing the mouth parts are the upper and lower **lips.** These are stiff plates like those of the body covering. Try to find all of these parts on your living and preserved specimens.

Parts attached to the thorax.—The first parts to attract our notice on our grasshopper specimens were the **legs** and the **wings.** We examined them closely and found the answers to certain questions about them (see page 71). The legs are so important that their use has given the insect its name, and the wings are its means of travelling from its home region to other feeding grounds, when the supply of food runs low. The wings are also used by the locusts to make their music, which is produced by rubbing the edge of the fore-wing with a file on the inside of the leg. When you hear a locust "fiddling," try to see it at work.

Parts attached to the abdomen.—There are no limbs or other large parts attached to the abdomen of the grasshopper. At first glance it appears to consist solely of ring-like **segments** (Fig. 76). If we look closely at a number of specimens, however, we shall see that in some the end of the abdomen is rounded, while in others it has two double points. These pointed spines form the digging part of an instrument with which the female grasshopper digs holes in the ground and lays eggs. It is called the **ovipositor,** or

"egg-placer" (from the Latin words *ovum*, an egg, *positum*, place). The female selects dry ground in which to lay her eggs, preferring the tops of knolls, dry roadsides, and other places where the grass is short. In such places the eggs are not likely to be injured by water in the spring. A wet season destroys the eggs as well as many of the insects that hatch.

More difficult to locate than the ovipositor is a smooth oval spot on the side of the first segment of the abdomen. This segment is incomplete, only the upper plate being present. The oval spot, which is the grasshopper's **ear drum,** is hidden by the large thigh of the hind leg. It is also partly covered by the wing. By examining your specimen carefully, however, you may see that this organ consists of a thin membrane, or skin, stretched tightly across an opening. Doubtless the ear is very sensitive to the music made by other grasshoppers, if not to all sounds.

Fig. 76. Side view of the body of a female grasshopper. Notice the segments of the abdomen and the spiracle in each, also the ear and the ovipositor.

Along the sides of the abdomen, just above the joint between the upper and lower plates of each segment, are a number of exceedingly small openings. These are the breathing pores or **spiracles** (*spiro*, I breathe). There are two spiracles also on each side of the thorax. It is possible to see on most specimens, even without a magnifying glass, the little hollows in which these openings occur. Tubes carry to all parts of the body the air that is breathed in through the spiracles.

If you have been able to find, by examining a living insect or preserved specimens, all of the parts mentioned

above, the grasshopper has shown you many interesting things. When you look closely at another kind of insect, you will find that it has three divisions of the body and other parts similar to those that we have seen in the grasshopper, though its parts will differ from those of the grasshopper in shape and perhaps in number. Our study of the grasshopper has shown us what to look for in other insects.

Life story of the grasshopper.—When you see a grasshopper on a blade of grass, usually he seems to be doing nothing in particular unless it be keeping out of your reach. How does he spend his time? Where was he yesterday, and what was he doing last week? Where will he be next week, if, in the meantime, he is fortunate enough to escape being caught by a bird or other enemy?

It would take a very long time to discover the whole life story of the grasshopper by our own observations. To see all that these insects have to show us we should need to spend many days out in the fields watching their doings. Since we cannot well do this, we must depend for some of our facts upon the work of other people. If we combine some of our own observations with many of the discoveries made by other observers, we shall have a complete story. Such a story is shown in the figure on the next page (Fig. 77).

Follow very carefully the life story as shown in these pictures and notice how the insect grows. The time required for each stage depends to some extent upon the weather, but the three stages follow more or less closely the seasons. The **egg stage** lasts through the winter and most of the spring. The **nymph stage,** with its five moults, occupies two to three summer months, being completed about the beginning of August. In this stage the insects, where they are numerous, advance as a great army, walking and hopping along, eating everything in their path. The **adult**

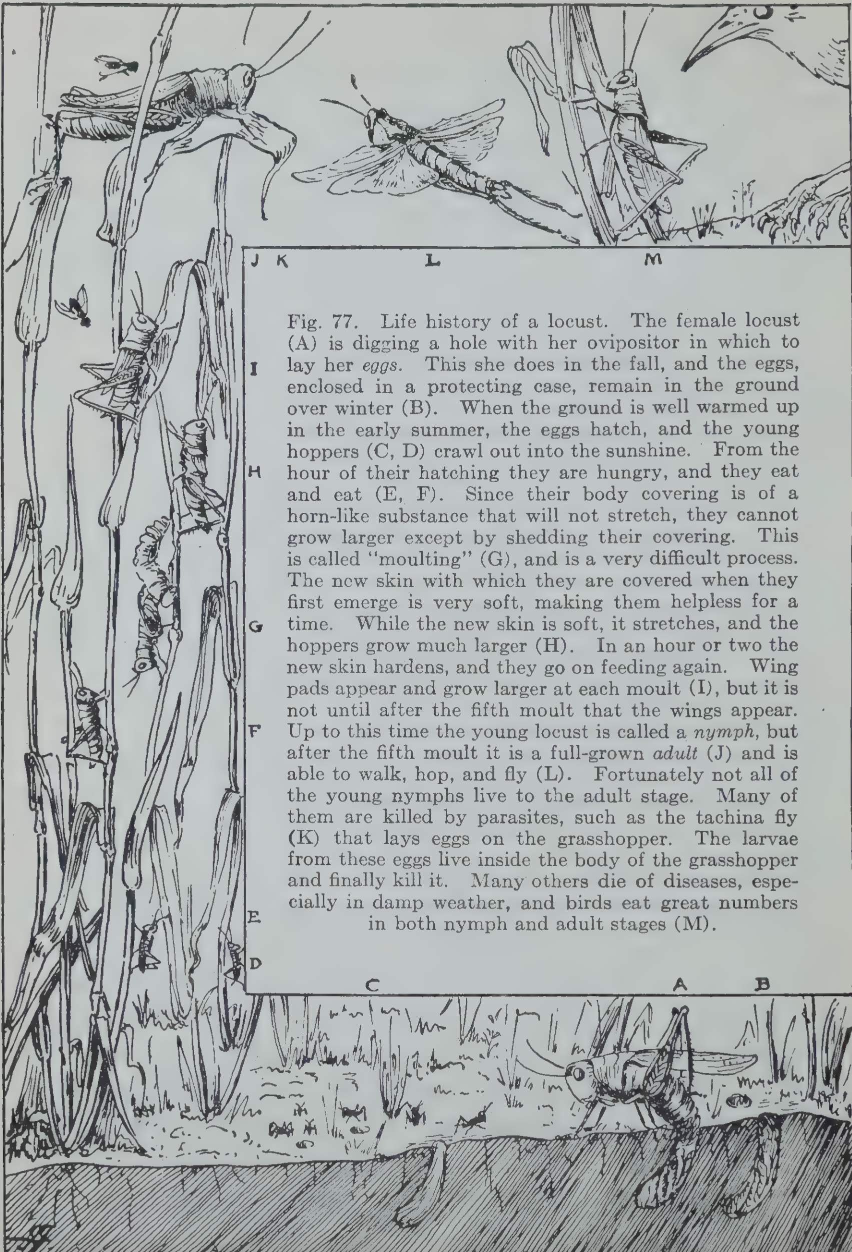


Fig. 77. Life history of a locust. The female locust (A) is digging a hole with her ovipositor in which to lay her *eggs*. This she does in the fall, and the eggs, enclosed in a protecting case, remain in the ground over winter (B). When the ground is well warmed up in the early summer, the eggs hatch, and the young hoppers (C, D) crawl out into the sunshine. From the hour of their hatching they are hungry, and they eat and eat (E, F). Since their body covering is of a horn-like substance that will not stretch, they cannot grow larger except by shedding their covering. This is called "moulting" (G), and is a very difficult process. The new skin with which they are covered when they first emerge is very soft, making them helpless for a time. While the new skin is soft, it stretches, and the hoppers grow much larger (H). In an hour or two the new skin hardens, and they go on feeding again. Wing pads appear and grow larger at each moult (I), but it is not until after the fifth moult that the wings appear. Up to this time the young locust is called a *nymph*, but after the fifth moult it is a full-grown *adult* (J) and is able to walk, hop, and fly (L). Fortunately not all of the young nymphs live to the adult stage. Many of them are killed by parasites, such as the tachina fly (K) that lays eggs on the grasshopper. The larvae from these eggs live inside the body of the grasshopper and finally kill it. Many others die of diseases, especially in damp weather, and birds eat great numbers in both nymph and adult stages (M).

stage lasts through the autumn until hard frosts come. In this stage the insects continue to eat, but they are not so ravenous as when they were growing rapidly. By the end of the season the females have deposited their eggs in the ground, ready to hatch a new generation of grasshoppers the next summer. All of these stages are shown in the figure.

Harm done by grasshoppers.—In Chapter VIII we learned something of the harm done by locusts or short-horned grasshoppers in Canada and in other countries. Read some of the stories in *Grasshopper Land* (see footnote, page 48), and you will see how in many countries famine and disease have followed the attacks of countless hordes of ravenous locusts, how in some regions the starving people have learned to use the locusts themselves as food, and how in other regions successful methods of defence have been found.

Defending prairie crops against grasshoppers.—In dry summers serious outbreaks of grasshoppers usually occur in various parts of Canada, and the farmers are faced with the problem of defending their crops against the attacks of these enemies. What can they do? Since all adult grasshoppers die in the fall, we can readily see that, if we devise a way of destroying the eggs or nymphs, we may not only put a stop to the damage this year, but may prevent the laying of eggs that would hatch next year.

The eggs may be destroyed by digging or ploughing the land in which they are laid. Some will be crushed, and others will be buried too deeply for the young hoppers to make their way out. In a field infested with millions of eggs, it is, of course, almost impossible to destroy them all, but, if most of them are destroyed, they will not cause serious damage the next year. Could this method be employed on roadsides, pasture fields, rocky hillsides, and such places?

As the nymphs cannot fly, they have in some places been stopped in their onward march by canvas barriers and by ditches into which they were swept and buried.[1]

In the Prairie Provinces, however, the most successful method of defending our crops against locusts is that of spreading poisoned food in the path of the advancing nymphs. Several kinds of poison have been used with good results, but they all consist chiefly of a mixture of bran and sawdust to which is added arsenic or other poison and some molasses, chopped lemons, or other flavoring to make it attractive. The hungry nymphs eat this mixture in preference to the tender wheat plants, and their travels soon come to an end. Poison bait laid out in all districts where locusts are fairly numerous this year will not only protect this year's crop, but will also prevent a very bad outbreak next year.[2] This method of poisoning grasshoppers would be much less successful if delayed until they had reached the adult stage, because, when they have wings, they fly about in feeding, and it is difficult to place the poison bait where they will find it.

Now we have seen from the grasshopper itself how its body is made up and what uses it makes of the body parts. We have seen also how and where it lives. This knowledge enables us to understand how we may defend our crops against its attacks.

In the days when people knew nothing about the life history of locusts, they supposed that the swarms came down from the clouds, or were sent in some mysterious way either to torment them or to feed them, according to the results that followed their visits. To-day we know that

[1]Read *Grasshopper Land*, Chapter XIII

[2]For full information, write to the Publications Branch, Department of Agriculture, Winnipeg, and ask for the latest bulletin on poisoning grasshoppers. In a recent Dominion government report, the savings effected in one season by using poison bait for grasshoppers were shown to be: Manitoba $17,000,000, Saskatchewan $20,000,000, Alberta $1,000,000.

they are numerous when many eggs have been laid and have been successfully hatched, and that, if we prevent either of these things from happening, there will be few grasshoppers.

Question Outline

(1) How many legs and wings did you find on your grasshopper specimen? (2) What differences can you see between the structures and the uses of the front wings and those of the hind wings? (3) What differences are there between the different pairs of legs? (4) How do you account for the size and shape of the third pair? (5) What are the uses of the claws and the spines that you observed? (6) Name the three divisions of the body of an insect. (7) What parts are attached to the head? (8) What are the uses of the antennae? (9) How do simple and compound eyes differ? (10) What mouth parts did you find? (11) Why does the thorax need to be large and strong? (12) In what different ways can the grasshopper move about? (13) What important parts are there on the abdomen? (14) Tell briefly how a grasshopper is employed during the spring and summer. (15) If a farmer finds many grasshoppers on his land this year, what should he do to prevent great damage to his crops next year?

CHAPTER XI

THE CABBAGE BUTTERFLY AND OTHER HARMFUL INSECTS

Importance of the cabbage butterfly.—In most gardens the pale-yellow cabbage butterfly may be found from early summer until autumn. This insect was brought to Quebec with supplies in English ships about 1860, and in twenty-five years it had spread to the West Coast, and from the far North to Central America. Insects that are able to spread as rapidly as this, especially when they feed upon garden plants as cabbage butterflies do, can do a great deal of harm. In order that we may defend our garden plants against them, we should know how they live and where they may be found in each of their stages. The cabbage butterfly is the only butterfly we have that is very harmful.

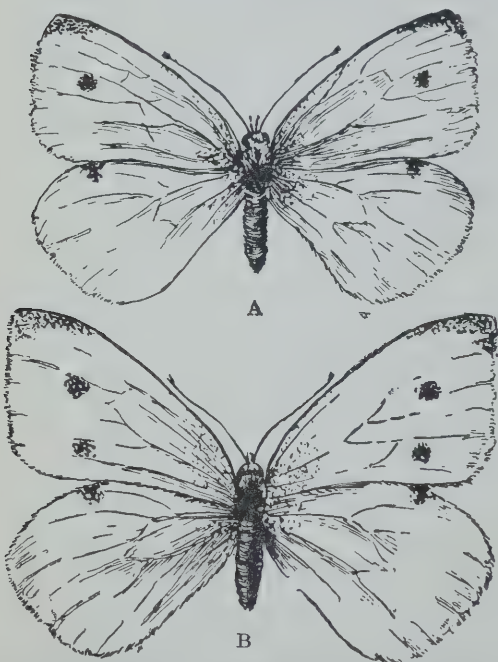


Fig. 78. A, Male cabbage butterfly. B, Female. Notice the difference in the number of black spots on the fore-wings. These butterflies are cream color or almost white and are very easily distinguished from all others.

Preparation.—Capture a few cabbage butterflies[1] and place them in the wire cages used for the grasshoppers (Fig. 69). Provide them with a few radish or mustard flowers. If they flutter about so that they are in danger of breaking their wings, cover them and keep them in complete darkness for a few minutes, uncovering them gradually when they have become quiet. If they are supplied with part of a cabbage leaf, some of the females will deposit eggs upon it. Eggs may also be found on cabbages in a garden where the butterflies are numerous. Look for the separate eggs, smaller than a pin's head, on the backs of the leaves.

The females may be distinguished by the fact that they have two dark spots on the fore-wing, while the males have only one (Fig. 78). Mount some male and some female specimens for the school collection (see Appendix, Sec. 4).

Find also some of the green caterpillars on cabbages in which holes have been eaten. Keep these caterpillars on cabbage leaves in a wire cage (Fig. 70). The leaves should be kept fresh by being stuck into a cut in the wet turf in the cage. The caterpillars will continue feeding, and some of the larger ones will change to the resting stage, or pupa.

Fig. 79. Eggs, larva (caterpillar), and pupa (chrysalis) of cabbage butterfly. The adult stage is shown in Figure 78.

You may also find in the garden some of these insects already in the pupa or chrysalis stage (Fig. 79). Late in the season you may find them about windows and doors, when the screens are being replaced by storm windows, but they are hidden about the garden in much greater numbers. Preserve eggs, caterpillars, and pupae to add to your mounted specimens in the school collection.

Comparison of the cabbage butterfly with other insects.—1. *Body parts.*—Having secured some specimens of the cabbage butterfly in each of its stages, we can see how it resembles and how it differs from the bee and the grasshopper. On the adult butterfly look for the body parts that you found in the other insects. Can you find all of them on the butterfly?

[1]For suggestions on making an insect net see Appendix, Sec. 2.

A. HEAD.—Antennae; compound eyes; simple eyes; mouth parts.

B. THORAX.—Wings (two pairs); legs (three pairs).

C. ABDOMEN.—Ovipositor; ear drum; spiracles.

A great many kinds of insects have all or nearly all of these parts. Notice, in the case of the cabbage butterfly, the following points: (1) The simple eyes cannot be seen. (2) The mouth parts are very different from the strong biting jaws of the grasshopper. Look for a long coiled tongue as shown in Figure 80. This may be uncoiled with the help of a needle. Is it like the tongue of the bee? Can the butterfly bite? What is its food? (3) Does the butterfly use all four wings for flying? Are the front and hind wings similar? What did you find in the case of the bee or the grasshopper? (4) You will find no sound-making part and no ear drums on the butterfly. (5) The ovipositor and the spiracles are present in the butterfly, but are not as easily seen as in the grasshopper. The sting of the bee is a somewhat altered ovipositor.

Fig. 80. Side view of head of cabbage butterfly. Notice the club-shaped antennae, the palps, and the long, coiled-up tongue.

2. *Life history.* — We find, when we look at the body parts, that the butterfly and the grasshopper or the bee are very much alike. We shall now study the stages in the life history of the butterfly.

When the butterfly lays an egg on a cabbage leaf, what hatches from it? Not a fully formed butterfly, but a *caterpillar.* The caterpillar is in reality a butterfly, but it has not yet developed wings, antennae, and other parts, and its abdomen is very long. In this stage it is called the **larva** of the butterfly (Fig. 79). Notice on your specimen the color and the marking. Is the body of the caterpillar hard or soft? Has it any stripes or spots? Is it easily seen against the green background of the cabbage leaf? Find its legs. It has six legs on the thorax and ten other temporary legs to hold up its long abdomen. When the caterpillar

hatches, it is about the size of a comma, but in less than a day it is twice that size, and in a few weeks it is about a thousand times its original size. What an enormous quantity of food it must eat to increase so greatly in size! Find its strong biting jaws and watch it biting pieces out of the cabbage leaf. Can you now see why the cabbage butterfly is a very harmful insect in the garden, and why the larva or growing stage is the one in which it does the most harm to plants?

What becomes of the caterpillar after it is fully grown? Some of those that you have in cages will change to the next stage (Fig. 79) in a few days. This is the **pupa,** or resting stage. It is often called a *chrysalis*. Notice that it is joined to a support by silk threads at the pointed end of the abdomen, and that it has a silken loop supporting it about the middle of its body. How does it fasten this thread around itself? Watch for a caterpillar changing to the pupa.

In the pupa stage the insect eats nothing. It is resting, and developing wings, antennae, and other parts that it will need when it becomes an adult. In the summer the pupa stage lasts only about a week. If insects find their way into a warm building, they may come out of their pupa cases at any time during the winter. Keep all your pupa specimens together, and see if any of them come out as butterflies. Those that go into the pupa stage in the autumn usually remain in that stage all winter. In a well-kept garden there are few places for pupae to live over winter, but, if weeds or rubbish are left about, the caterpillars find them and make use of them for shelter. A clean garden harbors few insect enemies.

When the time comes, the skin of the pupa splits, and the full-grown **adult** butterfly appears. Its wings are crumpled and soft, but they very quickly expand to their proper size and stiffen so that the insect can fly. The adult butterfly, as we have seen, feeds only on the nectar of

flowers and therefore does no direct damage. It does, however, lay eggs that hatch into hungry caterpillars.

The stages in the life history of the butterfly are: (1) egg, (2) larva, (3) pupa, and (4) adult, each form being unlike the others. The bee has the same four separate stages. The grasshopper, however, has three stages only in its life history: (1) egg, (2) nymph, (3) adult; and the nymph is very like the adult. The insects that have four stages in their life history, such as the butterfly and the bee, are said to have a complete set of changes or complete metamorphosis (*meta*, change, *morphe*, shape). Those that have a nymph stage, such as the grasshopper, are said to have incomplete metamorphosis.

How we may destroy biting insects that attack our plants.—Insects like the grasshopper, and the caterpillar larvae of butterflies and moths,[1] have strong biting jaws. These and many other insects bite pieces out of the leaves of plants. If the plants are sprayed with some poisonous substance,[2] the insects will eat it and be destroyed. Potato beetles are among the commonest garden insects for which these *food poisons* are used.

We have already suggested spreading poisoned bran mixture on the ground for grasshoppers. This is useful also for some kinds of caterpillars that live underground, such as the common cutworms. They come to the surface at night and will then eat the poisoned bran and molasses mixture if it is very fresh.

[1]Learn to distinguish moths from butterflies by: (*a*) *Antennae*—butterfly has club-shaped and moth has feathery antennae. (*b*) *Wings*—butterfly rests with wings erect and moth with wings flat along the back. (*c*) *Pupa*—butterfly pupa is a chrysalis; moth pupa is enclosed in a silken cocoon.

[2]The most commonly used poisons for leaf-eating insects are arsenate of lead and Paris green. For cabbages which have waxy leaves a sticker is required to keep the poison on the leaves. Cabbages should not be sprayed after the heads are half grown, as people eating them are likely to be poisoned. Pyrethrum powder, white hellebore, and lime are other remedies used to destroy cabbage caterpillars.

How we may destroy sap-sucking insects. — Plants are attacked by insects other than the biting varieties. These insects attack plants in the same way that mosquitoes attack people. They have mouth parts suited to piercing and sucking, instead of jaws for biting, and they suck the sap of the plant. They take from the plant the food that is required for its seeds or fruits, so that it is able to produce only a poor crop or none at all.

Fig. 81. Aphids or plant lice are sucking insects. How may they be destroyed?

Find some aphids, commonly called plant lice, or green flies on plants growing indoors or out. Figures 81 and 82 show their appearance. They are so common that you will not have to search far for them. They need not be kept in cages and, if house plants are growing in the classroom, should not be kept alive longer than is necessary to observe their actions. They are often so numerous on maple trees that the "honey-dew" which they produce falls as a sticky shower upon the leaves, which later become black with dust.

Courtesy U.S. Dept. of Agriculture.
Fig. 82. Aphids on a stem. Notice that some have wings while others have not. Can you see any of them sucking sap?

Ants sometimes keep aphids in "stables" as "herds of honey-producing cattle." Their "owners" defend them against lady beetles and other enemies and sometimes provide them with winter homes, bringing them out to their proper food plants again in the spring.

Observe aphids on a leaf or stem, and notice that some of them have their beaks sunk into the plant, evidently feeding. Some, you will find, have wings, and others have not.

Usually they are born with wings when food is becoming scarce, or when, for some other reason, it is time for the colony to move to another plant. When this time arrives, the old insects die, and the young ones with wings fly away to find a new food supply.

Since the aphids suck the sap from within the plant, they cannot be killed by spraying food poisons upon the leaves. The problem of destroying them has been solved in another way. From your knowledge of the way in which insects breathe, could you suggest a method?

If the insects themselves are sprayed with a soapy or oily solution, their spiracles become choked with the soap or oil, and they suffocate. The solution is frequently made more deadly by the addition of a poison made from tobacco, which is absorbed into the insect's body. To destroy the sap-sucking insects it is necessary actually to moisten their bodies with the *contact poison.*

All our efforts to defend ourselves and our crops against insects would be of little avail if we had not other help. We have already discovered the value, in this respect, of the predaceous or *"prey-catching" insects* and the parasitic insects that destroy millions of their harmful fellows (see page 52), and in our next chapter we shall study something of the value of birds. In the war upon destructive insects we also receive assistance from many insect-eating animals, particularly toads.

With the knowledge that you now have, you can understand the importance of studying insects and other animals. Without some knowledge of them we would not know how to set about destroying those that injure our plants, and we should probably destroy the friends whose help we so greatly need.[1]

[1]For complete instructions upon poisons for insects write to the Publications Branch, Department of Agriculture, Winnipeg (or Ottawa), asking for the latest bulletins on injurious insects.

Question Outline

(1) Make a table of comparison showing similarities and differences between the cabbage butterfly and the grasshopper or the bee, using the headings given under A, B, C, on page 84. (2) Compare the stages in the life history of the two insects. (3) In which stages is the cabbage butterfly harmful? Why? Is the adult harmful to plants? Does it help the plant in any way? (4) What occurs while it is in the pupa stage? What are the occupations of the adult? (5) Why are biting insects most destructive in the larva stage? (6) How may biting insects be poisoned? (7) What method of destruction can we apply to sap-sucking insects? (8) What other checks are there upon harmful insects? (9) Why is a knowledge of insects important?

CHAPTER XII

OUR FRIENDS THE BIRDS

We may learn many things about birds as they go about their daily work, especially if they find that they need not fear us. If we protect them against cats and provide them with bird-houses,[1] they will live contentedly as our closest neighbors. To answer some of the questions that we should like to ask about birds, however, we must have specimens at hand.

Wild birds are among the most difficult of all animals to capture. We should not attempt to procure a living specimen, for a wild bird, when captured, may injure itself in its struggles to escape and, if taken during the nesting season, may leave a nestful of young birds to starve or to die of cold. If, as sometimes happens, a wild bird is found dead, bring it into the classroom for all to see. The skin, with the feathers undamaged, may be preserved unmounted, or may be properly mounted by a skilled taxidermist, who can make it look like the living bird. Some of the birds shot as game in your district should be mounted in this way for your school collection.

Very tame birds, such as pigeons or chickens or even cage birds, are satisfactory living specimens for the first study of birds. Probably the most satisfactory arrangement for studying the bird at close range is to have one large bird, alive or mounted,[2] and one good colored picture of the same bird for each member of the class.[3]

In addition we shall need a supply of separate outstretched wings of domestic or game birds for study of the feathers. A collection of birds' feet, simply mounted, should be gradually built up, but, of course, no birds should be killed for the purpose of securing them.

[1]See footnote, page 104.

[2]For moth-proof mounts see Appendix, Sec. 15.

[3]The pictures should be mounted under glass so that they may be used repeatedly. See Appendix, Sec. 6. They may be obtained from *Nature Magazine* and other publishers.

Having obtained our mounted or living specimen and pictures, we shall try to find answers to some of our questions about birds. When we have seen our specimen bird close at hand, we shall know something of the lives of the birds that we see out-of-doors. To observe birds successfully, we must know what to look for.

Uses of the wings, the feet, and the bill.—A bird is so different from other animals that many people think of birds and animals as two different kinds of living things. In some ways these feathered animals are very different from all others, but perhaps the differences are not so great as they seem. Have birds two pairs of limbs, as we ourselves and many other animals have? What use do they make of their front or upper limbs? Are there any animals other than birds that fly? Examine the **wings.** Are they of any use for picking up or holding things? Front limbs that are spread out into thin, flat wings are very useful for flying through the air, but are of little use for other purposes.

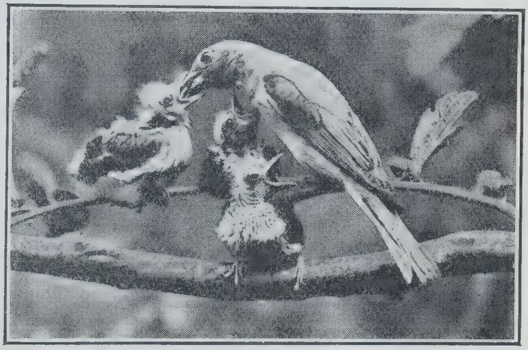


Photo by A. A. Allen.

Fig. 83. A mother bird (tanager) feeding her young ones. What would happen if we captured this bird for a specimen?

From observing the position or actions of your specimen, what uses would you say the bird makes of its **feet?** Can it use them for holding objects? What kinds of birds carry objects with their feet? Are the bird's feet like your hands or feet? Your hand can grasp an object because the first finger, the thumb, turns back and holds the object against the other fingers. Has your bird a thumb on its foot that

opposes the other toes and helps it to grasp objects? How many toes has it altogether? Can a bird pick up a small seed with its foot?

Now let us examine the bird's mouth. It is very different from the mouths of other animals. Has it any lips? What kinds of food does the bird eat? Is the **bill** type of mouth suited to taking these foods? Are the bills of most birds useful for picking up very small objects? Does the bird use its bill instead of hands for nest-building and for defence? Has the bird any teeth in its mouth? Where does it grind its food?

Fig. 84. The three types of feathers. A, Quill. B, Semi-plume. C, Down feathers. What are the uses of each kind? On a specimen of a quill feather pull apart the flat "vane" and see if you can hook the little thread-like divisions together again. Can you make a pen from the quill? Is it strong and elastic?

The body covering of feathers.—The bird's body covering of feathers is very different from the covering of any other animal. You have no doubt seen some of the very simple feathers remaining on the skin of a chicken when the larger feathers have been removed; some of them are like hairs with a few branches at the top, and some are very like the hairs of other animals. Of what use is the feather covering of the bird and the fur or hair covering of other animals? Do you think that broad, flat feathers keep out the wind better than fur would, when the bird is flying swiftly through the air? Do feathers part in the wind as fur does?

Are the feathers on the bird all alike? When a domestic fowl or game bird is being plucked, save some of the feathers from the wings, tail, and body. Find the soft, fluffy *down feathers* close to the surface of the body, and compare them

with the quill feathers or *flight feathers* that give shape to the wings and the tail (Fig. 84). The outer feathers covering most of the body surface are somewhat downy at the inner end near the body, and at the outer end are flat and firm like small quill feathers. These are called *semi-plumes*. Mount specimens of each of the three kinds of feathers in test-tubes for the school collection. Label them: (*a*) quill or flight feathers, (*b*) semi-plumes, (*c*) down feathers.

The down is more abundant on the bodies of ducks and other water birds than on land birds. Why do these birds require more down? What is the down of the eider duck used for? Why?

The wing feathers.—Examine an opened wing. Is the "arm" very wide and flat without the feathers? Could the bird fly if its wing feathers were cut off? What do you think is the special use of the large feathers of the wing? Watch birds flying and see if you can discover how they use the large wing feathers. Do they push down upon the air to hold themselves afloat? Is the size of the wings of any importance? The long, stiff feathers on the birds' wings are evidently useful for flight as well as for warmth. Which birds seem to fly more easily, the long-winged birds, like the gull, or the short-winged grouse and prairie chicken? Which can make the more sudden start? Does the sudden noisy take-off of the prairie chicken remind you of an automobile running in low gear? Why are they both noisy?

Now examine the three parts of the extended wing. The end section, from the tip to the "wrist joint," corresponds with your own hand; the middle section, extending from the wrist to the elbow, with your forearm; and the part from the elbow to the shoulder, with your upper arm. Find these three divisions and the three joints on the bird's "arm" and also on your own arm. From this comparison you will see that the bird's front limb is not very different from your own.

Special names are given to the large wing feathers used for flight because, in describing or identifying birds, it is necessary to refer constantly to special marks or colors on the different parts. Notice on the diagram (Fig. 85) that the greater part of the surface of the wing is formed by a row of **flight feathers.** The flight feathers on the "hand" are called primary flight feathers, or *primaries*; those on the "forearm" are *secondaries*; and those on the "upper arm" are *tertiaries*. Find the three kinds of flight feathers on your specimen.

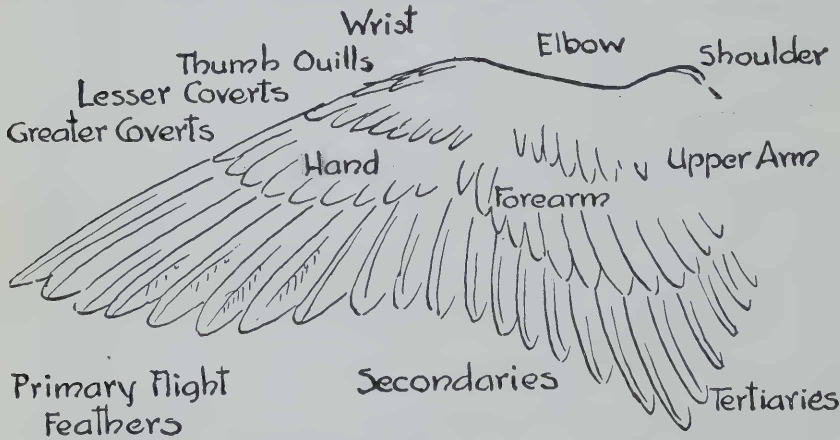


Fig. 85. The bird's arm and hand have the same plan as your own. Attached along the rear edge are the great flight feathers. These give a large surface that presses down upon the air and pushes the bird upward and forward. Notice the different wing movements of the crow, the gull, and the flicker.

The feathers covering the rest of the wing are called **coverts.** Hold your arm and hand in the same position as the wing and discover where to look for the little tuft of thumb feathers. Find the coverts and thumb feathers on your living or mounted specimen.

The tail feathers.—The birds that fly make use of their tail feathers for steering and for stopping in flight. Find on your specimen the large flight feathers of the tail. They are called the *rudders*. Covering their inner ends on the upper side are the *upper tail coverts*, and on the lower side

are the *lower tail coverts*. Do the birds with long tail feathers, such as swallows, seem to steer themselves in flight more easily than birds with shorter tail feathers? Watch a king-bird as he dashes from his perch to catch an insect on the wing and returns to sit motionless until another victim passes his way.

Colors of birds and moulting.—One of the most attractive features of our bird neighbors is their color. They share with the flowers the brightest colors common in the fields and the woods, but, because of their movement and song, are more noticeable than the flowers. In the spring, flowers open their corollas of brilliant hues, which attract their insect partners and thus enable the flowers to produce seeds. In the spring, birds also assume brilliant colors, which apparently attract their mates for the nesting season. Perhaps the bright colors are indirectly a protection also. In some cases the brightening of the dress in spring is due to the growth of new feathers. The old feathers fall out gradually, and a coat of new feathers with brighter colors grows in their place. When this change is taking place, the bird is said to be "moulting." Do fur-covered animals also change their coats? Do any other animals moult,—insects and snakes, for example?

Some birds don coats of dull-colored feathers in the autumn and change them for brighter coverings by moulting again in the spring. Many birds, however, have their bright spring colors hidden in their winter coats. They are covered by the dull-colored tips of the winter feathers. When these birds are ready to show their bright colors in the spring, they do not need to moult but have only to drop off the outer cloak of dull feather-tips and appear in their new spring suits. Does this method of changing its coat save the bird much discomfort? Ask someone who keeps a canary if the bird is comfortable when moulting.

In color many animals so closely resemble their natural surroundings that, as long as they remain still, they can be seen only with difficulty. A cabbage caterpillar, for instance, is very inconspicuous on a cabbage leaf. It is said to possess *protective coloration*. Some animals, on the other hand, are rendered very conspicuous by their colors. Of these the large monarch butterfly and the lady-beetle are examples. Such insects have a very objectionable taste, and birds soon learn to avoid them. They are said to have *warning coloration*. The bright coloring of our song birds cannot be a warning coloration, because they are regarded as delicacies by cats, weasels, some hawks, and many other animals.

Photo by H. C. Pearce.

Fig. 86. Lark sparrow on her nest. Look at the picture from a distance and see if an enemy could easily see the bird. Does this show protective coloration?

Is the coloring of birds ever protective? Consider the grouse, the meadowlark, the killdeer, and other birds that build their nests upon the ground. Do their coloring and markings afford protection, particularly for the female on the nest? Look at the lark sparrow on its nest (Fig. 86). Do its markings blend with its surroundings? Are they a protection?

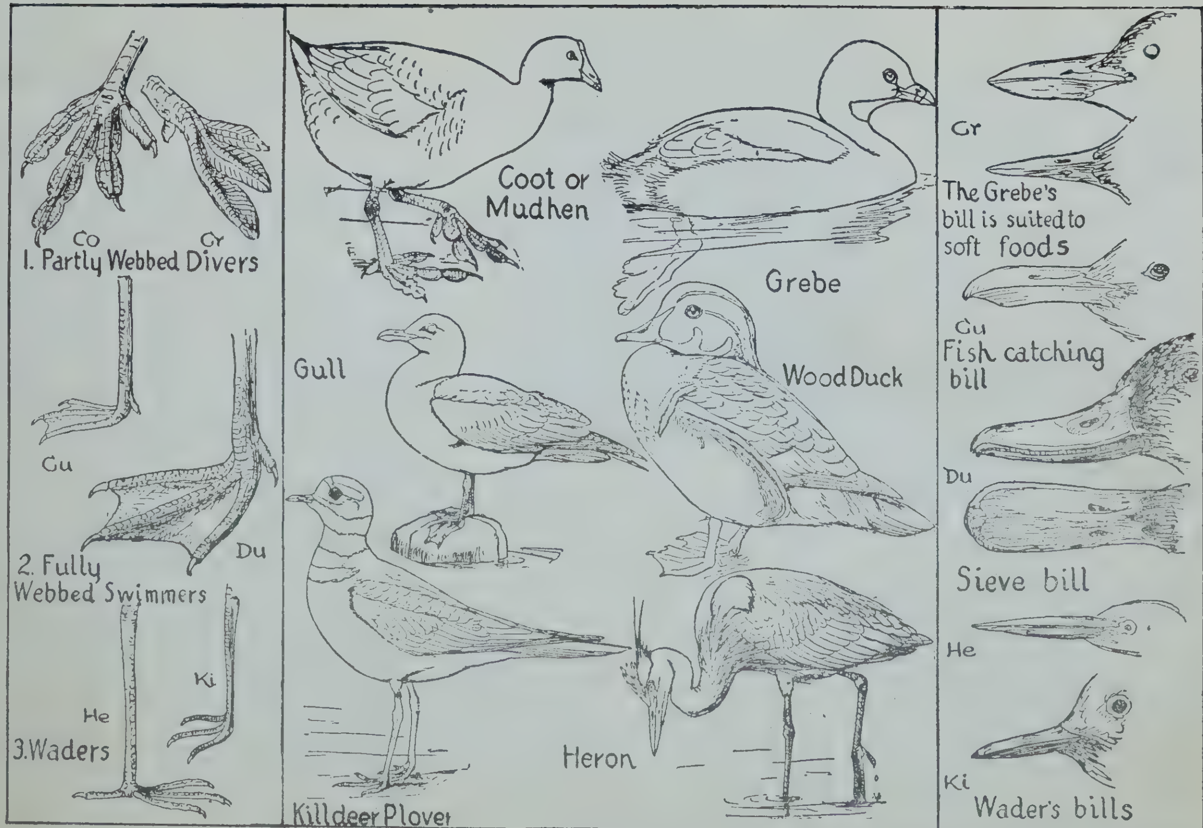
The bright colors of the male birds make them very conspicuous. In spite of this fact, they often choose the topmost twigs of trees or the tops of posts as perches from which to entertain their mates on the nests and their neighbors. In such cases they certainly do not try to hide from their enemies. Can there be any advantage in the conspicuous colors and songs of the male birds? If there are enemies in the neighborhood, which bird are they the more

likely to find, the brightly colored male, singing in the tree-top, or the dull-colored female on the nest? On its high perch is the male bird likely to be surprised by an enemy? At the approach of an enemy a bird often leaves its perch and flies to another tree-top a short distance away, leading the enemy off in a direction that is always away from the nest. Some birds cunningly pretend to be wounded and flutter helplessly along the ground, enticing the intruders away. Have you seen the killdeer plover do this? Is its nest very securely hidden? Do you think that the birds and their nests are safer because of the bright plumage of the male birds?

Points to observe about birds.—When we see a bird, two questions occur to us: "What kind is it?" and "What is its name?" It is not always easy to answer these questions, especially the second. Only a few people can name every bird that they see, but we can generally tell the kind or tribe to which a bird belongs if we look at it carefully and know what to look for. To answer these questions you should have a plan that will help you to look for points that show the character of the tribe.

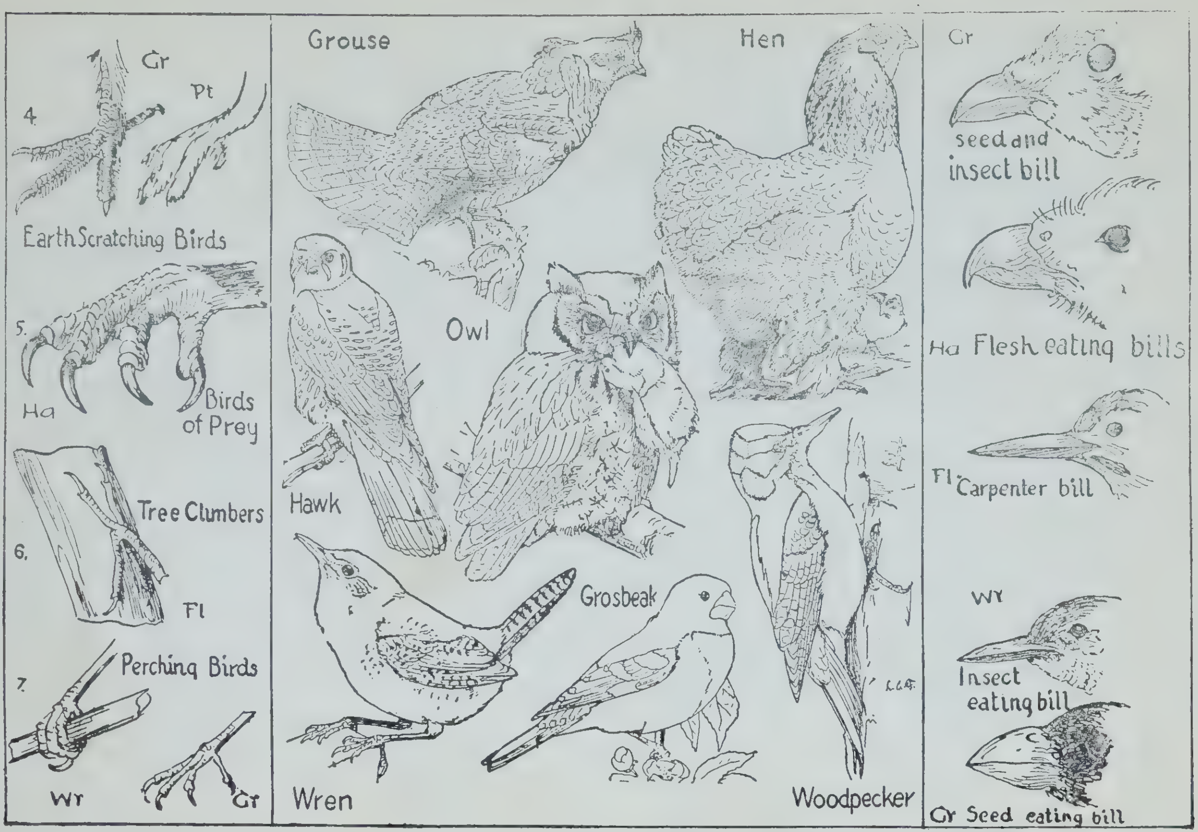
The feet and the bill of a bird are very noticeable. You may gain some skill in observing by noticing carefully first the feet and the bills shown in diagrams, and later those of specimens and birds out-of-doors. The diagrams on pages 98 and 99 have been prepared and arranged to give you practice in observing and to illustrate the seven great classes or tribes of birds.

Look at the outline drawing of each bird shown in Figure 87. Notice carefully also the feet and the bills shown at the left and the right. The notes following the diagrams will help you to see the important points, but you will come to know the seven tribes most easily by looking at the diagrams of the feet in the left margin.



Bird outlines reproduced by courtesy Slingerland, Comstock Co.

Fig. 87, A. Feet and bills of birds.



Bird outlines reproduced by courtesy Singerland, Comstock Co.

Fig. 87, B. Feet and bills of birds.

NOTES ON THE FEET AND BILLS OF BIRDS

Feet

1. Look at the grebe and the coot or mud-hen (Fig. 87, A). Their feet are only partly webbed, but they swim and dive so well that they escape from their enemies in this way instead of by flying.

2. The feet of gulls, ducks, geese, cormorants, and others are *fully webbed*, the toes being joined together. Do they dive or fly to escape their enemies?

3. The herons, plovers, snipe, and other shore birds have long, slender legs that enable them to wade out from shore to secure food. Their long toes prevent them from sinking in soft mud.

4. The grouse, ptarmigan, barnyard fowl, and other ground-dwelling birds have short legs with strong toes and blunt claws suited to walking on the ground and scratching for food.

5. The hawks and owls have powerful feet with heavy curved claws or talons suited to catching and holding prey.

6. The woodpecker's feet are strong and have sharp curved claws that cling on the bark of trees. Two toes turn forward and two backward. See how the tail is used as a prop.

7. The perching birds have slender feet with three toes turned forward and one turned back as a thumb. See how well the foot encircles the twig.

Bills

1. The bills of the diving birds are suited to taking any kind of soft food from the water.

2. The gull's bill is hooked at the tip. Does this make it better able to hold a slippery fish? The ducks take in particles of food mixed with water. Then they squeeze out the water through the sieves along the sides of their broad bills.

3. The bills of the wading birds are long and slender. With them the birds reach down into the water for small fish or into the mud for insects or other soft food.

4. The bills of the earth-scratching birds are strong but sharp. In winter they must live upon seeds, berries, and buds, but in summer they catch insects as well.

5. The bills of birds of prey are heavy, sharp, and curved like their claws, enabling them to tear the flesh of their victims.

6. The bills of the "carpenters" are very strong and somewhat square. The ends have a chisel edge that can chip out holes in trees. The tongue is a hard, sharp spear that pierces insects and draws them out of their tunnels.

7. Some perching birds have slender, fine-pointed bills useful for picking insects and their eggs out of crevices. Others have short bills suited to cracking hard seeds and dry fruits. Many of these birds live chiefly on weed seeds.

Having become familiar with the feet and the bills of birds of each of the seven tribes, you will have no difficulty in determining to which tribe any bird belongs. You will then be able to answer our first question: "What *kind* of bird is it?"

To answer the second question—"What is its *name*?"—you will need more help. You may secure the necessary help in two ways. Either you may question some one who has made a study of birds, or you may look up the bird for yourself in a bird book, such as *Birds of Western Canada*,[1] which gives descriptions and pictures of many kinds of birds.

If you were to say to a friend who has studied birds, "I saw a brownish-colored bird this morning—what is the name of it?" he might be obliged to reply, "I do not know." This would be true, because you would not have told him enough about it to enable him to decide whether it was a sparrow, a meadow-lark, or a prairie chicken. He might ask you to describe the bird, and, if you could do so, he would probably be able to tell you its name.

The following plan for observing a bird suggests six points for which you should look. Each of the points you may observe in a few seconds, and when you have seen them, you will be able to describe the bird very well.

Plan for Observing a Bird

1. *Kind or tribe.*—Is the bird a diver, swimmer, wader, earth-scratching bird, bird of prey, tree-climber, or perching bird?

2. *Size.*—Is it larger or smaller than, or about the same size as (*a*) sparrow, (*b*) robin, (*c*) crow? Everyone knows these birds.

3. *Shape.*—Is it slender, thick-set, long-necked, duck-like, etc.?

4. *Colors.*—What colors and markings are there on its body, head, wings, tail?[2] Do any colors flash into view as it flies?

[1]This book has been prepared by Mr. P. A. Taverner, who has made a thorough study of the birds of Canada and has described them and their habits in detail. A copy of this book should be found in every library.

[2]For the names applied in bird-book descriptions to the smaller parts see diagram on page 22 of *Birds of Western Canada*.

5. *Movements.*—Are the bird's movements slow and quiet, or quick and nervous? Is its flight smooth, or up and down in a wave-like motion? Does it move about alone or in flocks?

6. *Song or call.*—What sounds does it make when singing? When calling? When frightened? Does it sing while perched or on the wing?

If you had had this plan in your mind when you saw the bird that you were asking your friend about, you would have said to him, "Can you tell me the name of the bird that I saw this morning? It was *perched* on a telephone wire near a poplar bluff; in *size*, it was a little smaller than a robin; in *shape*, it was rather a slender bird with a long tail; its *color* was reddish brown on the back with lighter speckled breast; its *movements* were rather slow and careful, but graceful; its *song* was like the warbling of the robin." On hearing a description like this, your friend would be much more interested in helping you, because he would see at once that you had a plan for observing birds. He would probably be able to say without hesitation, "It must have been a brown thrasher, one of our best songsters." Then, if you appeared to be interested, he might go on to say that the brown thrasher, like his cousin, the catbird, is a mocking-bird, imitating the sounds of many other birds. He might also tell you that the brown thrashers are becoming more numerous across the prairies, and that they are very useful birds because more than half of their food consists of grass-hoppers and other harmful insects.

Instead of asking your friend about the bird, you might have looked for it in a bird book, in the tribe called the *Perching Birds*. There you would probably have found many interesting things about the brown thrasher, the catbird, and other mocking-birds.

Practical Exercise

On a card or slip of paper make a list of the six headings suggested in our plan for observing a bird. Take this out-of-doors with you and

observe a bird that lives near your home or school, noting on the card, as accurately as you can, each of the six points given in the plan. From these notes, write in your note-book a careful description of the bird. Be sure that each sentence says exactly what you intend it to mean.

When you have described the bird, mention the *time* and *place* in which you saw it, and tell what it was doing at the time. Birds spend their time chiefly searching for food, feeding, carrying away food, carrying straws, playing about in flocks, chattering, quarrelling, flying (on long journeys or short flights), calling to their mates, singing, nest-building, and caring for their young.

If you write down just what you see at a particular time in a particular place, you will have a record that is entirely your own. No one else sees just what you see, and if your account is a true one, you will have written a brief chapter of new bird history. It is very important that every detail that you write down should be correct, because other people have no way of knowing what happened, except from your account of it. Birds do many things that are not described in books. Some of these you may be the first to see and to record.

When you have completed your first bird record, make similar records of other birds. Make the first observations on cards and the finished records in your note-book.

Since birds are very difficult to draw, the observations made in your note-book may be illustrated by printed outlines such as those used on pages 98 and 99. Outlines twice as large as those in the figure, printed on water-color paper, are excellent for this purpose.[1] After you have made your observations, you may wish to color the outlines, or to draw the feet, the bill, or perhaps the whole head of your bird.

Migration of birds in spring and autumn.—You now have a plan for observing a bird and for writing a record of what you see. You are able, therefore, to help the many observers who are keeping records from year to year of the dates on which each kind of bird arrives from the south in the spring and sets out on its journey southward again in the autumn. This movement of birds from south to north and back again is called **migration,** and the records of the

[1]Copies of these outlines, drawn by Louis Aggasiz Fuertes, a famous bird and animal artist, are obtainable on loose-leaf sheets of water-color paper at about one cent each from book-stores or from the publishers, The Slingerland, Comstock Co., Ithaca, New York.

dates are important in deciding which birds need protection and when they need it.

Your class is probably making a bird migration chart, showing the residence and migration dates of a number of birds that you know.[1] If so, make a copy of it in your notebook and continue to mark on it the dates of arrival and departure of the birds. A copy of your class chart should be sent to the secretary of your nearest natural history society.

Fig. 88. Ducks and blackbirds collecting in flocks in autumn. Geese migrating.

Doubtless you have often warmly welcomed the first robin in the spring. Probably, also, you have often noticed in the autumn that the birds gradually disappear. You may have seen the blackbirds gathering in flocks before they departed, or the wild geese flying high overhead in their V-shaped formation (Fig. 88).

It is not difficult to think of reasons for these birds leaving our country in winter. Not only does the climate become cold and uncomfortable for them, but the insects disappear, and much of the other food is deeply buried under the snow and ice. Moreover, the days become so short that there

[1]A form for the chart is given in the Suggestions to Teachers on page xvi. An official chart of this kind, together with bird lists and much valuable information about birds, bird-houses, bird enemies, bird books, etc., is contained in Bulletin No. 52, *Birds in Relation to Agriculture,* issued by the Publications Branch, Department of Agriculture, Winnipeg. Write for a copy.

is not sufficient daylight in which to search for the food that remains.

Have you ever wondered, on the other hand, why the birds come back to us from the sunny south? Why do they not stay where it is warm all through the year? This is a puzzling question, and we have not yet found an entirely satisfactory answer to it. Nor can we explain fully how the birds are able to find their way over great stretches of country and sometimes over the sea. Perhaps we may be able to discover part of the explanation.

We have observed that young birds in the nest are fed chiefly upon insects, not upon seeds. Suppose, then, that the very large number of birds that winter along the shore of the Gulf of Mexico all attempted to raise their families in that region. When the young hatched, they would require perhaps five to ten times as many insects as the parent birds had been finding a few weeks before. There would probably not be enough for all of the nestlings. It would not be surprising, then, if the birds wintering in the Gulf region should learn to spread out over the surrounding country and build their nests where they could find a plentiful supply of insects. They might fly up the river valleys until they found that their neighbors were not too numerous or too close to them and might then build their nests and raise their families. The rivers would be an easy guide to them in returning to the Gulf in the autumn. Many birds from the Gulf region actually do migrate up the Mississippi valley and across the height of land into Canada. Birds may be guided in their journey by lakes, mountains, coast-lines, or other land-marks, as well as by rivers.

In coming north for the summer, do birds gain in hours of daylight? How many hours of daylight are there each day in the *far* north?

Protecting our birds and their homes.—We frequently

see birds carrying materials with which to build their nests, and we occasionally know where the nests are hidden. We also know that, if a nest is visited often or if the eggs are touched, the parent birds are likely to be so sure that harm will come to their young ones that they will desert the nest. It is a great pity that, by our carelessness and lack of understanding, we sometimes cause birds to leave their nests. They are among our most helpful friends, and it is gross ingratitude on our part to drive them away from their homes. People who understand how birds live and the difficulties that they must meet do not interfere with their homes.

One nest containing eggs should not, therefore, be chosen for study by a whole class, unless it is placed in a specially favorable position, where it may be seen from a distance through field glasses or a mirror.[1] If there is a nest near your home, you may be able, if you understand birds, to watch them without disturbing them in any way. You may then write a full record of their experiences in building the nest and raising their family.

Even empty nests should not be collected in numbers, because the birds may need them again the next season. One or two, or at most a few nests, carefully mounted in the school collection so that they may be used from year to year, will be sufficient to show how wonderfully the birds weave together twigs, grass, rootlets, or other materials, or how they cement them together with mud.

For the purpose of protecting the birds that migrate to the south in winter, we in Canada have made an agreement or treaty with our neighbors, the people of the United States. They have agreed not to kill our insect-eating birds during the time that they are spending the winter in the south, and we have agreed not to destroy them while they are

[1]A high nest may be observed, without molesting it, by viewing it through field glasses or by attaching a small mirror to a long stick and holding it above the nest.

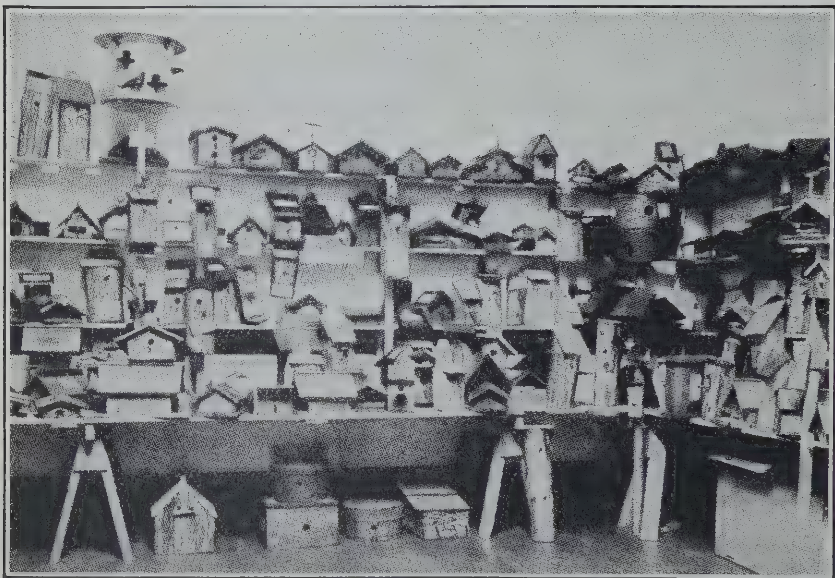
nesting and while the young ones are growing up in the north. This wise agreement, which is called the Migratory Birds Convention, was made by our governments so that the same birds would be protected in both countries. They are protected not only because they are pleasant neighbors but also because the grain and fruit crops and the wild plants of both countries need the protection of the birds against their insect enemies. The agreement can be kept unbroken only if every person in both countries is careful to observe it. You share this responsibility in your district. One person may break the treaty by killing a bird or by destroying its eggs and may avoid being punished by the law, but he cannot break the treaty without doing injury to the fruit crops and grain crops of both countries and injuring the reputation of his countrymen for sportsmanship and fair play. We should be very careful, therefore, that none of the protected migratory birds are killed or their eggs taken.[1]

Harmful birds.—Not quite all of our birds are protected by law, because there are a few that do harm and that are becoming too numerous. How can we decide whether the crow, for instance, should be protected or destroyed? We should not condemn the crow because he is black or even because he steals a few chickens. The grasshoppers destroyed by the crows pay many times over for the chickens that they kill, and even where they pull up the young corn plants they probably pay for all that they take by killing insect enemies.

To decide whether the crow, or any other kind of bird, deserves protection, we must study its habits and carefully

[1]The birds that are protected by the treaty are: all migrant insectivorous birds (this includes most of the perching birds), some sea birds, and waders and shore birds except a few which are classed with the ducks and other game birds. The latter are protected except in the short shooting season in the autumn. Write to the Game Branch, Department of Agriculture, for a copy of the Game Laws of the province.

Fig. 89. Wild ducks on government reserve. This shows the result of protecting birds.



Courtesy Ottawa Humane Society.

Fig. 90. Bird-houses made by the boys in one of the schools in Ottawa. These provided homes for many bird families.

compare the good and the harm done. The crow would be protected if destroying chickens and corn were his worst crimes, but, unfortunately, they are not. He has the bad habit of eating the eggs of other birds. When crows become too plentiful, other birds become scarce, and the insects that the destroyed birds would have eaten are left to feed upon the grain crops. When the Department of Agriculture finds that crows have become too numerous, it offers prizes or introduces some other plan that will induce people to decrease the numbers of the black nest-robbers.[1] The good and the harm done by each kind of bird are being constantly studied. To make these records of the greatest possible value, observations must be made in all parts of the country. You may help in this work by sending records of your observations to a bird club or natural history society.

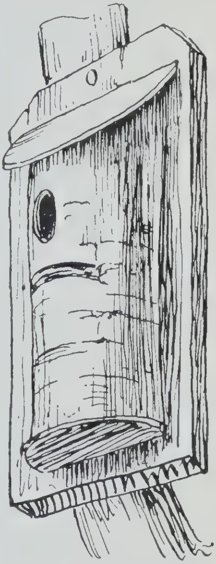


Fig. 91. Birds come to our houses because they protect them against cats, crows, squirrels, and other enemies, and also against heat, rain, and hail. Look in bird bulletins for dimensions of houses to suit various birds and for many other good suggestions.

Our responsibility to birds.—The birds are our friends and helpers against our insect enemies. We are all responsible for their protection and encouragement. Some of us may help in this work by establishing on our lands *bird sanctuaries* where birds are protected throughout the year. There are many bird sanctuaries in Western Canada, some large, others small. Some of us may help by building bird-houses about our dwellings (Fig. 91). Birds nest in these houses to be safe from crows, squirrels, and other enemies. Some may help by capturing stray cats. Cats

[1]Have you had a "crow competition" in your district? Write to the Department of Agriculture, Winnipeg, and ask for suggestions for conducting such a competition.

are among the worst enemies of birds; they do little good and much harm when allowed to roam about out-of-doors. Others may help by destroying crows and gophers, both of which are cruel enemies of birds. And everyone may help by finding new information about bird ways or by explaining to others the value of birds and their need of protection.

Question Outline

(1) How many limbs has a bird? For what does it use each pair? (2) For what is the bill used besides eating? (3) What is the body covering of birds, and how is it suited to their needs? (4) What three types of feathers have you found? On what parts of the bird? (5) Compare the wing of the bird with your arm and hand as to sections and joints. (6) What is the use of the quill feathers of the wings? of the tail? (7) How do birds obtain a "new spring coat" with bright colors? (8) Is there any advantage in the bright colors of the male bird and the dull colors of the female? (9) What is the advantage of the speckled coloring of many ground-nesting birds? (10) What are the seven classes or tribes of birds as seen from their feet? Name two birds of each tribe that you recognize when you see them. (11) When you wish to learn the name of a bird, what six points do you look for in order to describe it? (12) Why do birds go south, and why do they return to the north? (13) Why should we protect nearly all of our birds? (14) Why was the Migratory Birds Convention signed? (15) What five birds of Western Canada do more harm than good? In *Birds of Western Canada* read about the economic status or good and harm done by the following: hawks, pages 178, 185; short-winged hawks, page 186 (sharp-shinned, page 186, Cooper's, page 188, goshawk, page 189); sapsuckers, page 230; crow, page 261.

PART III

STUDY OF TEMPERATURE CHANGES AFFECTING PLANT AND ANIMAL LIFE

CHAPTER XIII

TEMPERATURE AND ITS MEASUREMENT

Changes taking place in autumn.—As summer passes, and autumn wears away into winter, we find that the apparent path of the sun in the sky changes. Not only does the sun rise and set farther and farther south, but the height to which it rises in the sky each day becomes gradually less. The days become shorter, and, on an average, the weather becomes steadily colder.

With shorter days and colder weather come many changes in both plant and animal life. Trees and shrubs that were clothed in the green leaves of summer become decked with yellow, red, and gold. Soon their garments flutter away. Many plants die to the ground, leaving roots and seeds to grow in the coming year. Others die outright after producing seed. Like the leaves, birds and animals also change color. Notice the robin's faded red breast. Look for the gray-colored rabbit when the dark carpet of the woodlands changes to white. When the insects are tucked away for the winter, and the worms dig deep, the songs die out of our forests, because the birds fly far to the south to seek better feeding grounds and a warmer climate. Many of our animals, such as the bear, the badger, and the gopher, make homes for themselves in the earth in order

to pass the winter months safe and warm beneath the frost and snow. (See Frontispiece.)

We have seen that changes take place in plants and animals as autumn advances and the days become colder, or as we say, the temperature lowers. We might now ask the questions, "What is temperature?" and "How can it be measured?"

Temperature.—Heat the end of a piece of iron to redness and thrust it into a beaker half filled with cold water. After a minute feel the end of the iron, and also the water. You will notice that the iron has been cooled while the water has grown warm. The iron must have given up part of its heat to the cold water. When one object will give up part of its heat to another, we say that the two objects are at different temperatures.

If you put your hand into ice-cold water, you will find that it soon feels cold because it gives up some of its heat to the water; but if you place it in warm water, it becomes warmer because the water gives up part of its heat to your hand. We say that your hand and the water are at different temperatures because one gives up heat to the other. We might therefore define temperature as *the degree of heat of one object as compared with another.*

In the instances recorded above, we relied upon our sense of touch to tell differences in temperature. Can we always rely upon our sense of touch? To answer this question perform the following experiments.

Experiment I

Apparatus.—Three large beakers or cans, one containing very cold water, one containing hot water, and one containing luke-warm water (Fig. 92).

Method.—Put one finger of your left hand into the beaker of very cold water and a finger of your right hand into the beaker of hot water. Leave them there for a minute or two. Then quickly put both fingers into the beaker of luke-warm water.

Observations.—(1) Does the luke-warm water seem hot to the finger of your left hand? (2) Does the luke-warm water seem cold to the other finger?

Conclusions.—(1) Does your left hand take up heat rapidly from the the luke-warm water and lead you to think that it is hot? (2) Does your right hand lose heat rapidly to the luke-warm water and make you think that it is cold? (3) Can we depend upon our sense of touch to tell us how

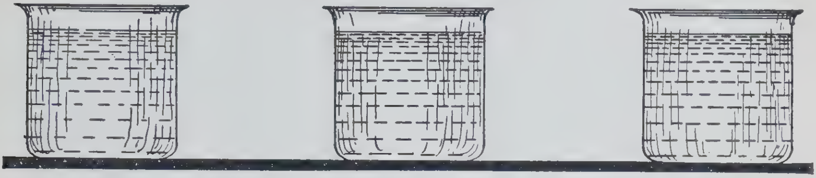


Fig. 92.

Beaker containing ice-cold water. Beaker of water as warm as your hand. Beaker of water as hot as your hand can endure.

hot or how cold an object is? In other words, can we depend upon our sense of touch to tell us accurately the *temperature* of an object?

Experiment II

Apparatus.—A piece of iron and a piece of wood, both of which have been in the room for some time. (A school desk that is partly metal will serve the purpose.)

Method.—Hold your hand on the wood for a moment and then place it on the piece of iron.

Observation.—Which feels the colder?

Conclusions.—(1) Since both objects have been in the same room for some time, will each be at the temperature of the air in the room? Does the iron *feel* colder? (2) Can we depend upon our sense of touch to indicate to us *how hot or how cold* an object is? In other words, can we reply upon our sense of touch to tell us the *temperature* of an object? (3) Did you ever walk into your home on a cold day and remark that the room felt comfortable while someone who had been indoors for some time declared that the room actually felt chilly? Explain. (4) Have you ever gone from an overheated room to one moderatelv heated to find that it felt cool to you? Explain.

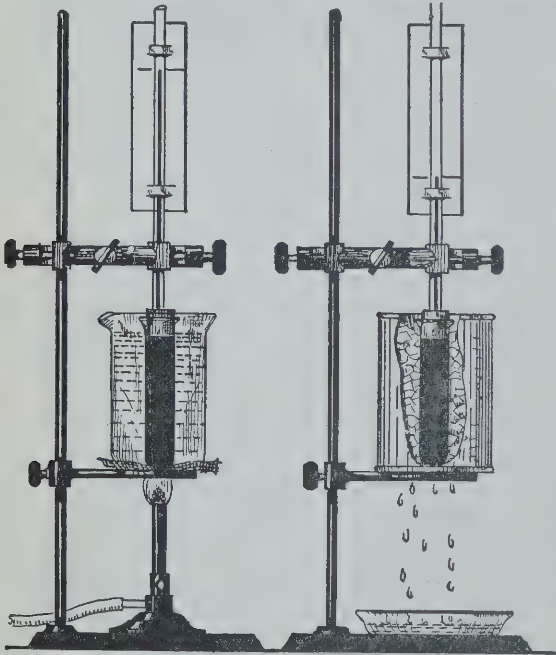
The accurate measurement of *temperature* became a real problem to the scientists of a few hundred years ago. Like you, they discovered that they could not depend upon their sense of touch to tell them how hot or how cold an object

was. In the end, they solved the difficulty by devising an instrument with which you are probably familiar. Such an instrument is no doubt hanging on the wall of your classroom, and there may be one in your own home. What is it?

The Thermometer (*thermos*, heat, *metron*, a measure).

Object.—To construct a simple thermometer and make a scale on it.

Apparatus.—A test-tube, a glass tube of small bore and about two feet long, a one-holed rubber stopper to fit the test-tube with the hole the proper size for the glass tube, paper on which to put the scale, a burner, a stand, wire gauze, glycerine, snow or crushed ice, a tall beaker nearly filled with recently-boiled distilled water. (Melted ice, melted snow, or clean rain water will do.)



A Fig. 93. B

Method.—To a test-tube one-third full of glycerine, colored with a little red ink, add enough water to fill it completely. This must have been recently boiled to expel dissolved air. Shake it till all the glycerine is dissolved. Put one end of the glass tube through the hole in the cork, making sure that it does not project below the bottom of the cork. Insert the cork tightly into the test-tube. See that no air becomes entrapped below the cork. Some of the liquid in the test-tube will rise into the glass tube. Have sufficient liquid in the test-tube to ensure that it will rise about half-way up the glass tube when the cork is fitted properly. Set up the apparatus as shown in Figure 93, A, taking care to put the test-tube well down into the beaker of

water. A little mucilage will help to hold firm the paper to be used for the scale.

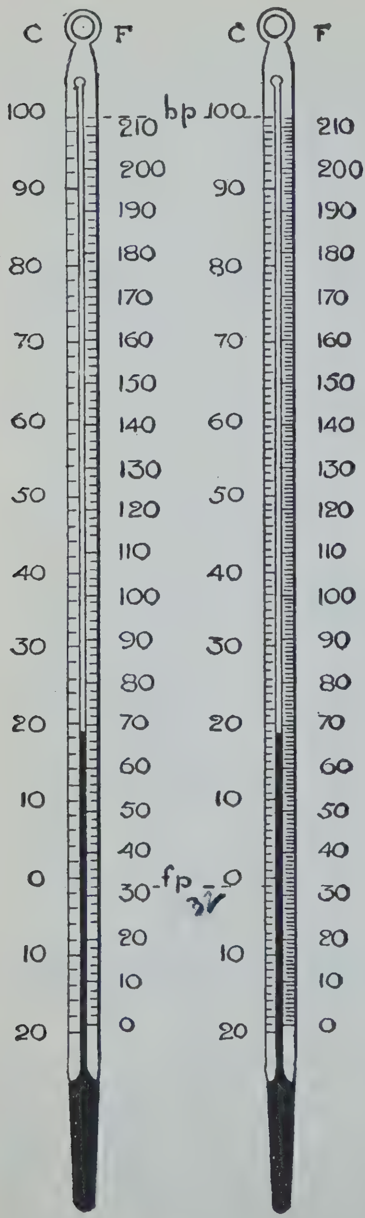
Now heat the water in the beaker till it boils. Watch the behavior of the colored liquid. When the liquid in the tube ceases to rise, make a mark on the paper which is fastened to the glass tube. This will indicate the height to which the liquid rises when the liquid in the test-tube is at the temperature of boiling water. Label this mark **Boiling Point.** Continue the boiling for a few minutes.

Then remove the beaker of boiling water and replace it with a can which has a few holes punched in the bottom and contains melting ice or snow (Fig. 93, B). Again notice the behavior of the colored liquid. When the liquid in the glass tube ceases to descend, mark the new level and label it **Freezing Point.** This mark will indicate the height of the liquid in the glass tube when the liquid in the test-tube is at the temperature of ice which is melting. Leave the test-tube in the melting ice for a few minutes longer, then remove the can of ice.

Observations.—(1) What does the liquid in your thermometer do (*a*) when its temperature is raised? (*b*) when its temperature is lowered? (2) Does the liquid seem to rise steadily as the temperature of the liquid in the test-tube is gradually raised to boiling point? Does it seem to fall steadily as the temperature of the liquid is gradually lowered? (3) Does the liquid in the tube rise any higher after it reaches boiling point even when heating is continued? Does it fall any lower after it reaches freezing point, even when kept in the melting ice or snow for some time.

Conclusions.—(1) Have you made a thermometer that will indicate variations in temperature ranging from the temperature of boiling water to that of ice which is melting? (2) If the space between boiling point and freezing point on the paper were divided into a number of equal divisions, would you have made a scale by which you could read all variations in temperature between these two points? Suggest a suitable number of divisions to make and mark them on your scale.

Suggestions and points for discussion.—(1) Use your thermometer to find the temperature of (*a*) a large beaker filled with hot water and (*b*) a large beaker filled with cold water. (2) Obtain two thermometers with different scales marked on them or one thermometer having two scales on it. Find freezing and boiling points and discover how many equal divisions are marked on each between these two points. (3) If you had used a very small test-tube holding but a small amount of liquid when making your thermometer, would its temperature have changed more quickly from boiling to freezing point? (4) Examine the thermometer in your room and suggest why the bulb on it, which corresponds to the test-tube on your



A Fig. 94. B

simple thermometer, is small. (5) Why would your large thermometer be of little use to give you the temperature of small bodies, such as a cup of water? To answer this question, consider the effect of the large test-tube of liquid on the temperature of the cup of water. (6) Extend the scale you made on your thermometer above boiling and below freezing.

Structure of the thermometer in common use.—An ordinary thermometer consists of a glass tube of small bore, with a bulb at the bottom in which a liquid, such as mercury or colored alcohol, has been sealed. On this tube, or on a suitable support to which it is attached, are placed one or two suitable scales. If we can read the scales on this instrument, we shall be able to measure the temperature of various objects.

Examine carefully the diagram of two thermometers (Fig. 94). You will see two scales marked on each. The one marked C. is named the Centigrade Scale and was first proposed by Celsius, a Swedish scientist, in 1740, while the other, marked F., is called the Fahrenheit Scale, named after the German instrument-maker who designed it. The numbers on

each scale indicate "degrees Centigrade" or "degrees Fahrenheit." Zero degrees Centigrade (O°C.) represents the temperature at which pure water freezes, while one hundred degrees Centigrade (100°C.) marks the point on the scale to which the liquid in the tube will rise when it is heated to the temperature at which pure water boils[1].

On the Centigrade scale 0°C. is called *Freezing Point*; 100°C. is called *Boiling Point.* The space on the scale between O°C. and 100°C. is divided into 100 equal divisions, usually numbered in tens. On some thermometers, every degree is marked by a short line (Fig. 94, B), but on others only every second degree is marked thus (Fig. 94, A). How is each thermometer in the diagrams marked? How is your home or classroom thermometer marked? By extending the scale above 100°C. and below O°C., a wider range of temperature can be measured. Degrees below zero Centigrade (O°C.) are shown in writing or printing as minus degrees C. For example, we would indicate 10° below zero C. in writing as – 10°C. How many degrees' difference in temperature are there between –8°C. and 8°C.?

[1] At places above sea-level pure water boils at a temperature a little below 100°C.

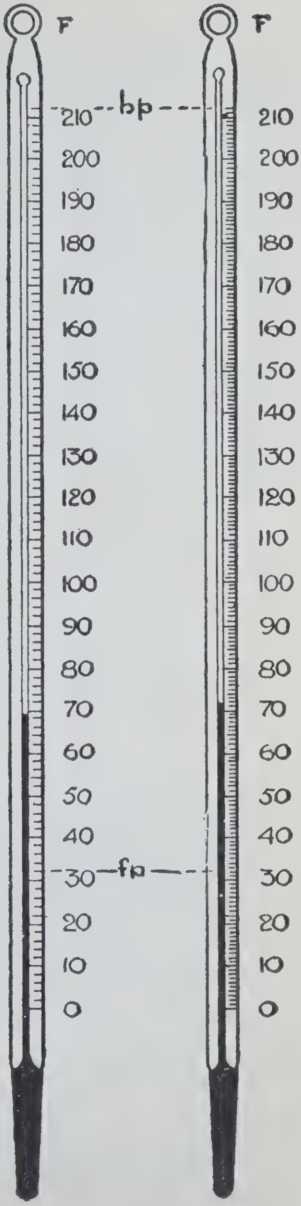


Fig. 95.

On the Fahrenheit scale, zero point was chosen by Fahrenheit to represent the lowest temperature that he could obtain by a mixture of ice and common salt. It is said that this was the lowest temperature that Fahrenheit could produce artificially at that time. On this scale boiling point is marked 212°F., while the freezing point of pure water is marked 32°F. (Fig. 95). How many degrees are there between freezing point and boiling point? How many degrees are there on the Centigrade scale between these two points? You will see that 180 Fahrenheit degrees indicate the same variation in temperature that is shown by a difference of 100 degrees Centigrade.

We employ the Fahrenheit scale on thermometers used for registering weather temperatures. When we are having "zero weather," is the temperature at freezing point? How many degrees below freezing would the weather be if the thermometer read 14°F.? 0°F.? −20°F.?

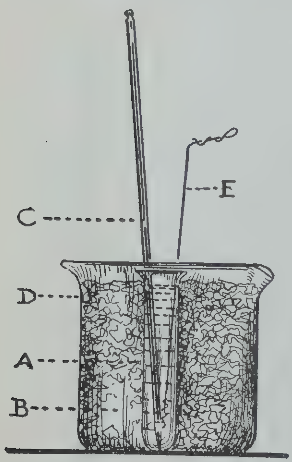


Fig. 96. A, Test-tube containing pure water. B, Freezing mixture of ice and common salt. C, Thermometer. D, Beaker. E, Stirring rod.

Does pure water always freeze at the same temperature?—Sincefreezing point on the thermometer indicates the temperature at which pure water freezes, it may be interesting to test two or three samples of pure water to see if all of them freeze at the same temperature.

Experiment

Object.—To see if pure water always freezes at the same temperature.

Apparatus and materials.—Three test-tubes, a beaker, ice or snow, common salt, a Centigrade thermometer and a Fahrenheit thermometer or one thermometer with both readings on it, three samples of pure water (Fig. 96).

Method.—Partly fill three test-tubes with pure water. (If distilled water cannot be obtained, use clean rain water or melted snow.) Insert the Centigrade and the Fahrenheit thermometers, or the one marked with both scales, into one of the test-tubes and place it in the freezing mixture in the beaker. Keep the water stirred with a piece of wire. Take the reading on each scale from time to time and record the temperature at which the pure water begins to freeze. Repeat the process with the second and third samples of pure water. Use the same thermometers each time.

Observation.—At what temperature does each sample of pure water freeze?

Conclusions.—(1) Do you think pure water always freezes at the same temperature? (2) If you had a thermometer that was not marked off in degrees, why could you use pure water for finding the freezing point? (3) How could you find where to place the freezing point on it?

Suggestion.—If several thermometers are available, it may be possible to have the above experiment carried out by various groups of pupils.

Do various samples of pure water boil at the same temperature?—If you have used an accurate thermometer, you will have found that freezing point on it indicates the temperature at which the pure water *freezes*. Now perform the following experiment to discover at what temperature various samples of pure water *boil*.

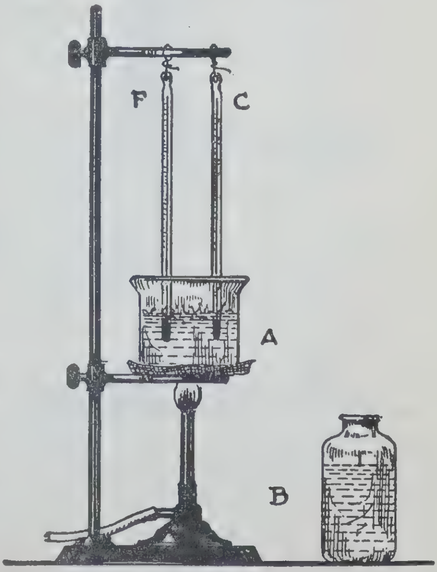


Fig. 97. A, Beaker of pure boiling water. B, Second sample of pure water. C, Centigrade thermometer. F, Fahrenheit thermometer.

Experiment

Object.—To test the boiling point of samples of pure water.

Apparatus. — A stand, wire gauze, a burner, a Centigrade thermometer, a Fahrenheit thermometer, or one thermometer marked with both scales, a beaker, two samples of pure water (Fig. 97).

Method A.—Suspend the two thermometers in the beaker partially filled with pure cold water, making sure that each bulb is below the surface of the water. Heat the water till it boils, noticing the temperature indicated on each scale from time to time. Record the temperature, C. and F., at which the water boils.

Method B.—Repeat Method A, using the second sample of pure water.

Observations.—(1) At what temperature does the pure water boil in each case? Record readings on both thermometers. (2) Is the boiling point as shown by your experiments the same for each sample of water? (3) If you had a thermometer not marked off in degrees, why could you use pure water for finding the boiling point?

Conclusion. — Do various samples of pure water boil at the same temperature?

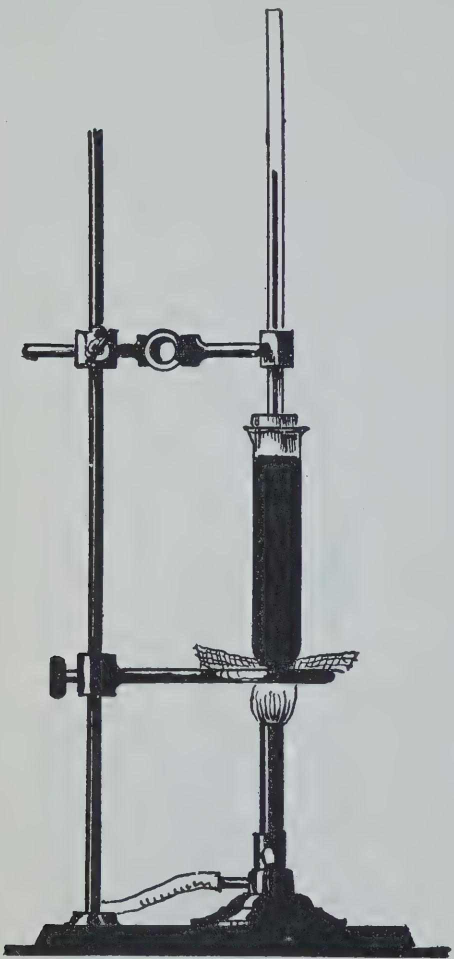


Fig. 98. Would the liquid rise more rapidly if a tube of smaller bore were used? Can you suggest why the tube in the thermometer has a very small bore? Why is water not a good liquid to use in a thermometer? What liquids are used? Why is there a bulb in every thermometer?

NOTE.—You will probably find that the boiling point is not quite the same as that marked on the thermometers. Were you to repeat this experiment from day to day, you would also find that the boiling point of the water would vary slightly. These variations occur because the temperature at which a liquid boils is affected by variations in air pressure. The greater the pressure of the air, the higher is the boiling point. If you have a barometer in your school, find out for yourself whether air pressure varies from time to time. If you have no barometer in your school and wish to construct one, follow the instructions given in Chapter XXXVII.

Principle on which the thermometer depends.—Let us now try to discover the principle upon which the thermometer is based. To do this, carry out two experiments.

Experiment I

Object.—To find the effect on the volume of a liquid when its temperature is raised and lowered.

Apparatus.—The model thermometer previously constructed (Fig. 98).

Method.—Heat the liquid for some time (do not boil it) and then allow it to cool.

Observations.—(1) Does the liquid rise in the glass tube when it is heated? (2) Does the liquid rise more and more as it becomes hotter? (3) Does it fall slowly and steadily when allowed to cool again to the temperature of the air in the room?

Conclusions.—(1) Does a liquid expand when heated? (2) Does a liquid contract when cooled?

Experiment II

Object.—To find the effect on the volume of a solid when its temperature is raised and lowered?

Apparatus.—A metal rod, such as iron or aluminium, about two and a half feet long and about one-quarter inch in diameter, two burners, a

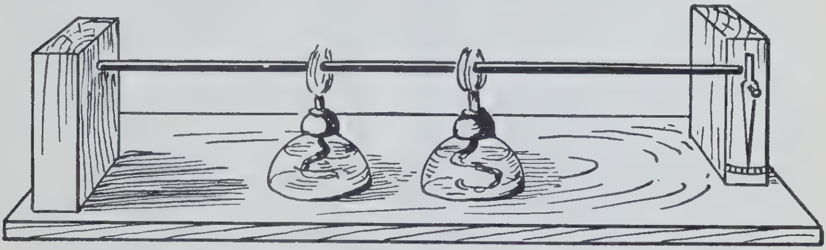


Fig. 99. When the rod is heated, which way will the tip of the pointer move?

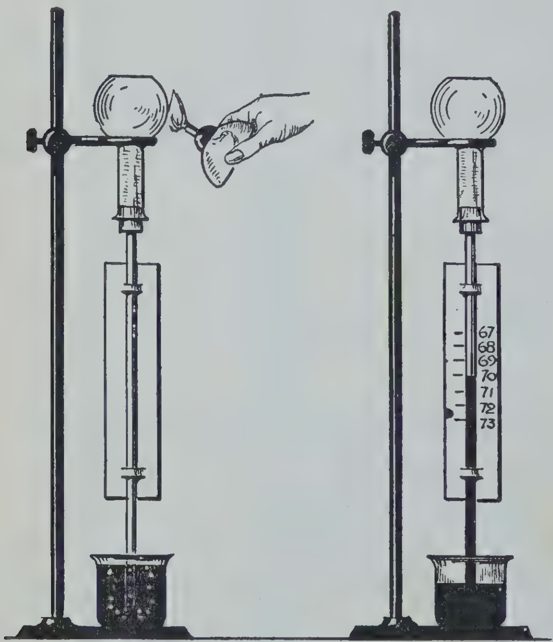
pointer (this can be made from tin), two short pieces of $2'' \times 4''$ scantling attached to a board (Fig. 99).

Method.—Support the rod firmly in a horizontal position, either by a metal stand or by placing it in a hole bored in a piece of scantling. Fasten the pointer on a support and place the short arm of the pointer against the end of the rod. Then heat the rod by the burners. By moving the burners back and forth along the rod, a greater amount of rod can be heated. After heating for some time, remove the burners and allow the rod to cool again.

Observation.—Is the pointer moved one way when the temperature of the rod is raised and the other way when the temperature lowers? What does this show?

Conclusions.—(1) Does a solid, such as iron, expand when its temperature is raised? (2) Does a solid contract when its temperature is lowered?

From the first experiment we learn that water expands when its temperature is raised by heating, and contracts when its temperature is lowered. Other liquids, such as mercury and alcohol, behave similarly. Making use of this principle, the present-day thermometer has been constructed.



A B

Fig. 100. Why do bubbles of air escape through the water when the air in the flask is heated?

In the second experiment we see that a solid expands when its temperature is raised by heating and contracts when it cools. Other solids, glass for example, do the same. Heating and cooling of the glass in a thermometer tends to change the size of the bulb and the bore slightly, but the effect on the rise and fall of the contained liquid is so little that, for ordinary readings, no account need be taken of this variation.

How one of the first thermometers was made.

Object.—To study the structure of one of the first thermometers made.

Apparatus.—A Florence flask, a cork, a glass tube about two feet

long, a beaker containing a little water, a piece of paper with two slits near each end to be used in making the scale. (A little coloring material may be put in the water, such as potassium permanganate or ink.)

Method.—Set up the apparatus as shown in Figure 100, A. Then raise the temperature of the air in the flask slightly by holding a burner near the flask or by placing your warm hands on the flask. Discontinue the heating when a few bubbles of air have escaped through the water. Then allow the air to cool again to the temperature of the room. If, on cooling, the water rises more than half-way up the glass tube, empty it out and repeat the process, but bubble out a little less air this time. If, on the other hand, it does not rise half-way up the glass tube the first time, bubble out a little more air. Mark the place on the paper at which the water stands when the air in the flask has cooled to the room temperature. Hold a little ice or snow on the flask for a moment.

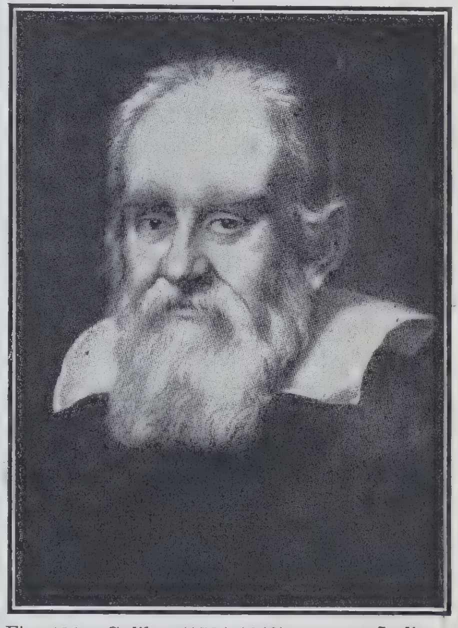


Fig. 101. Galileo (1564-1642), a great Italian scientist, who loved to experiment. He constructed one of the first thermometers.

Observations.—(1) Since some of the air escapes when the flask is heated, what must happen to a gas, such as air, when its temperature is raised? (2) What does a gas do when its temperature is lowered? (3) Does air expand considerably with small changes in temperature?

Conclusions.—(1) Does a gas, such as air, expand when its temperature is raised, and contract when the temperature lowers? (2) Could this apparatus be used to indicate variations in temperature? (3) As air expands considerably for small variations in temperature, could this thermometer be used to show great changes of temperature?

Suggestion.—From a mercury thermometer, find the temperature of the air in the room and place this reading opposite the level of the water in the glass tube when the air in the flask is at room temperature. As variations in room temperature occur from time to time, thus causing the water in the glass tube to ascend or descend, add more readings.

In 1592, at the University of Padua in Italy, Galileo, an Italian scientist, constructed a thermometer similar to the one that you have now set up. It was one of the first thermometers ever made. He knew that solids, liquids, and gases expand and contract as their temperatures vary, but, in making his thermometer, he chose a gas rather than a liquid because gases expand more than liquids or solids.

Suggested Questions and Problems

(1) What kind of thermometer have you in your schoolroom to record room temperature? What is its present reading? Compare this reading with that on a Centigrade thermometer. (2) Using a Centigrade thermometer and a Fahrenheit thermometer, or one with both scales on it, take the temperature of each of the following: (*a*) the air outside, (*b*) tap or well water, (*c*) ice water, (*d*) a mixture of ice and salt. (3) To get practice in reading thermometers and to compare the readings shown on the two scales, carry out the following suggestion and record your readings: (*a*) Put a Fahrenheit thermometer and a Centigrade thermometer, or one marked with both scales, into a beaker of cold water and record the temperature as shown on each. Then heat the water to boiling, taking readings on the two scales at the same moment at short intervals as the temperature of the water rises. This can best be done when two pupils work together. (*b*) Then insert each thermometer into a beaker of cold water and cool the water by adding ice. Finally put a little salt in with the ice and water. Take readings from time to time and notice what is the lowest temperature that you can obtain. (4) On a chart similar to the one shown below,

Date	Fahrenheit Reading	Centigrade Reading

keep a record of the weather temperature for a month. Take the reading each day at the same hour and in the same place. (5) Examine the thermometer in your room and answer the following questions: (*a*) How many degrees are there between boiling point and freezing point? (*b*) At what

intervals are numbers placed on the scale? (*c*) How many subdivisions between these numbered intervals are shown by short lines? (*d*) How many degrees does each small subdivision represent? (*e*) Which scale, C. or F., is on your thermometer? (6) (*a*) Hold your hand on the glass tube of your thermometer opposite the small thread of contained liquid, and notice how much the liquid rises. Then place your hand on the bulb of the thermometer. Does the liquid rise more quickly now? Explain. (*b*) Why is a bulb found in every thermometer? (7) (*a*) Of what use is a

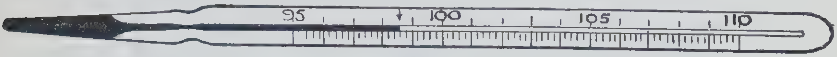


Fig. 102. A clinical thermometer.

thermometer to each of the following people: a doctor, a dairyman, a florist, a housewife, a breadmaker? (*b*) Can you think of any other uses to which we put thermometers? (8) Hang a thermometer in a convenient place out-of-doors in the shade. Make daily readings each month, taking the temperature at the same time each day. Keep your readings on charts similar to the one shown on page 126. Prepare a separate page for each month, but keep them together in a loose-leaf book or note-book to be left in the school. Different pupils may take the readings each month. (9) How many degrees above freezing is the average temperature of our May and June evenings? Can you imagine the effect on growth in your province if that temperature were about fifteen or twenty degrees lower? (10) If the temperature of the various rooms of your school is regulated by thermostats, find out how they operate. (11) Find out, if you can, how a maximum and minimum thermometer works.

Review Outline

(1) What is "temperature"? Outline an experiment to show whether we can depend upon our sense of touch to tell differences in temperature. (2) How could you construct a simple thermometer and make a scale on it? (3) Draw two common thermometers side by side. Mark on one the Centigrade scale, and mark on the other the Fahrenheit scale. (4) At what temperature does pure water always freeze? How could you show this to be true? (5) How did you show the effect of heat on (*a*) a liquid, (*b*) a solid, (*c*) a gas? What is the principle on which a liquid thermometer depends? (6) How did you construct a thermometer similar to the first one made and make a scale for it?

Temperature Chart for February

Date	19	19	19	19	19	19	19
1							
2							
3							
4							
5							
6							
7							
8							
9							
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CHAPTER XIV

WATER TO ICE

The freezing of water in the fall and the covering of our rivers, lakes, and ponds with a layer of ice are so familiar to us that we do not notice anything exceptional about them. Let us see what happens in such circumstances. From experiments that we performed recently, we learned that a gas, such as air, a solid, such as iron, and a liquid, such as mercury, each contracted more and more as it was cooled. They would all have continued to contract had we cooled them to still lower temperatures. Water, however, does not do this. To discover for yourself the behavior of water as it cools perform the following simple experiment.

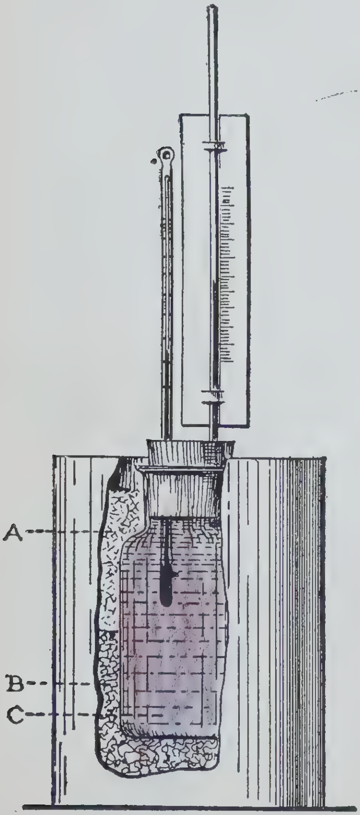


Fig. 103. A, Mixture of snow or crushed ice and common salt. B, Crumpled paper or sawdust. C, Water.

Experiment

Object.—To find out what changes take place in the volume of water as it cools and freezes.

Apparatus.—A wide-mouthed bottle about four inches in length and two inches in diameter, a two-holed rubber stopper to fit tightly into the bottle, a glass tube of small bore about two feet long that will fit tightly in one hole of the stopper, a Fahrenheit thermometer (a Centigrade thermometer may be used) that will fit tightly in the

other hole of the stopper, a long strip of paper with a line drawn lengthwise on it marked off into millimetre divisions, enough distilled water to fill the bottle completely (clean rain water, or snow water, will make a good substitute), snow or crushed ice, common salt, a tin can considerably larger in diameter than the bottle and slightly longer, paper to stuff around and under the bottle in the lower half of the can (Fig. 103).

Method.—Set up the apparatus as shown in the diagram. See that the glass tube does not project below the lower surface of the stopper. Allow the thermometer to extend down about one inch beyond the stopper. Attach the scale to the glass tube by mucilage to prevent it from moving. The water should rise about half-way up the tube when the cork is inserted in the bottle. Be careful not to allow any air to remain between the stopper and the water in the bottle. Heat the water to about 104° F. (40° C.) before pouring it into the bottle.

As soon as you place the bottle in the tin can on a layer of crumpled paper, as shown, mark on your scale the level of the water in the tube and record the temperature of the water as shown by the thermometer. Put a mark opposite the first level. Then, after stuffing paper in the tin can around the lower half of the bottle, pack snow, or crushed ice, and salt, mixed approximately in the proportions of three to one respectively, around the upper half of the bottle. It will be necessary to add more from time to time, as required.

Now watch carefully both the thermometer and the level of the water in the tube and record in the following chart your observations.

Temperature F. or C. of the water in the bottle.			Number of millimetres' change in the level of the water in the tube from the first level.	
	F.	C.		
Temperature of First Reading	?	?	....	. 0 ..
At......................	86	30	....	......
At......................	77	25	....	......
At......................	68	20	....	......
At......................	59	15	....	......
At......................	50	10	....	......
At......................	39	4	....	......
At......................	32	0	....	......

If a Centigrade thermometer is being used, put small marks on the scale attached to the glass tube indicating the exact level, at 8°, 6°, 5°, 4°, 1°, 0°.

If a Fahrenheit thermometer is being used, put small marks on the scale attached to the glass tube indicating the exact level, at 45°, 42°, 39°, 36°, 34°, 32°.

When the water in the bottle commences to freeze, notice the rate of change in the level of the water in the glass tube. Allow the freezing to continue till the level rises somewhat above the original level.

Observations.—In addition to keeping a record on your chart, make the following observations in your note-book: (1) Does water continue to contract as its temperature lowers more and more? At what temperature does water occupy its least volume? (2) Is considerable water forced up out of the bottle as the water in it changes to ice? (3) Is there a considerable increase in volume when water turns to ice?

Conclusions.—(1) In what way is the behavior of water on cooling different from that of other substances that you have studied? (2) At what temperature does pure water contract to its least volume? (3) Why is considerable water forced up out of the bottle as the water in it changes to ice?

NOTE.—Any kind of water could be used in this experiment. Water with salt dissolved in it (well water, for example), however, will freeze at a slightly lower temperature than does pure water.

The effect of changes in temperature on water.—Pure water continues to contract as its temperature is lowered, until it is cooled to 39°F. or 4°C.; but, if it is cooled below this temperature, it gradually expands again till it reaches freezing point, which is 32°F. or 0°C. About this temperature it expands considerably. This explains why a cubic foot of water at 39°F. or 4°C. is heavier than at any other temperature: for the simple reason that there is more water in it. If kept in the freezing mixture, it will change to ice, which is a solid, and, in so doing, will expand rapidly. As water expands about one-tenth of its volume when it turns to ice, a cubic foot of ice weighs considerably less than a cubic foot of water. Since any substance which weighs less per cubic foot than a given liquid will float in that liquid, ice floats on water.

In the autumn the water at the surface of a pond or lake gradually cools and so contracts, thus becoming heavier. It sinks below the warmer expanded water underneath. This, in turn, being pushed up to the top, will cool and contract. In time, the whole lake will cool to 39°F. or 4°C., at which temperature the water will have contracted to its smallest volume. The surface water will now expand as it cools below 39°F. or 4°C. and will remain at the surface, being lighter than the under water. This it will continue to do until it freezes, forming ice.

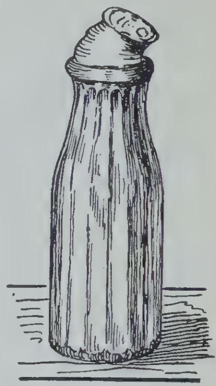


Fig. 104. Explain what has taken place.

Have you ever heard of travellers in the Northland digging a hole in the snow and getting into it for protection from the cold, biting winds? Do you know that our prairie chickens force their way under the snow in the cold winter for shelter? Did you ever read about the homes which the Eskimos build of ice and snow to provide a shelter for them in their bitterly cold land (Fig. 105)? As snow will protect people, so ice on the surface of water forms a blanket which protects the under water from the cold winds and prevents it from cooling rapidly. Thus, unless a body of water is very shallow, it will not lose enough heat to freeze to the bottom. At the most, only a few feet of surface water ever freezes in temperate climates.

Fig. 105. A snow-house in Coronation Gulf.

Now let us consider a few things that would result if water behaved like other substances, which contract more and more as their temperature is lowered. In the first place, the ice would be heavier than water, and would consequently sink to the bottom, leaving the surface water continually exposed to the cold winds. These would quickly carry off much heat, causing more and more of the water to freeze, till finally the whole of a body of water would be a solid mass of ice. In the second place, the fish and other water animals would be destroyed, perishing from cold and lack of water. In the third place, it would be impossible to thaw a whole lake of ice during the summer, and therefore we would not be able to use ships on our lakes and oceans to carry people and cargoes. Fourthly, the presence of large masses of ice over a great part of the whole earth would so chill our summer winds that growth of plants would be almost impossible in the parts of the world that now have a temperate climate. Fifthly, our water supply for the winter would be endangered. Can you think of other serious things that might result? What a difference it would have made to this world on which we live if water had behaved like most other substances when they gradually cool and change to a solid.

Question Outline

(1) Find out the revenue derived by Canada or by your own province from her fisheries for any one of the last few years. (2) At what temperature does a cubic foot of water weigh the most? (3) Which would weigh the more, (*a*) a cubic foot of ice or a cubic foot of cold water? (*b*) a cubic foot of water at 32° F. (0° C.) or at 39° F. (4° C.)? State the reason in each case. (4) Why does ice float on water? (5) In the experiment which we have just performed, what would have happened to the bottle had no water been able to escape from it? You might prove your answer by filling a test-tube or ink bottle with water, and, after corking it tightly, freeze the water. (6) Why do water pipes sometimes burst in winter? (7) Could

a lump of earth containing considerable water remain intact if freezing occurred? Account for the fact that rough, lumpy ploughed ground of the fall is crumbled to fine earth by the spring. (8) What is likely to happen to rocks during the winter if they contain crevices which hold water? Suggest one means by which rocky mountains are broken up and in time become soil. (9) Why would the model thermometer that you made some time ago not give accurate readings between 0° C. and 4° C. or between 32° F. and 39° F.? Does this trouble arise when mercury or alcohol is used in a thermometer? (10) Explain why it is necessary to drain the water out of the radiator of a car in very cold weather.

Review Outline

(1) What changes take place in the volume of water as it cools and changes to ice? How could you show that these changes do take place? (2) Most substances contract more and more as they are cooled. If water were to do this, suggest some serious consequences that might follow.

CHAPTER XV

FORMATION OF CRYSTALS

We have all observed the wonderful patterns formed on window-panes where moisture was frozen, that is, turned to a solid. We have also been attracted by the various shapes of snowflakes as they fell upon our coat sleeves (Fig. 106). In

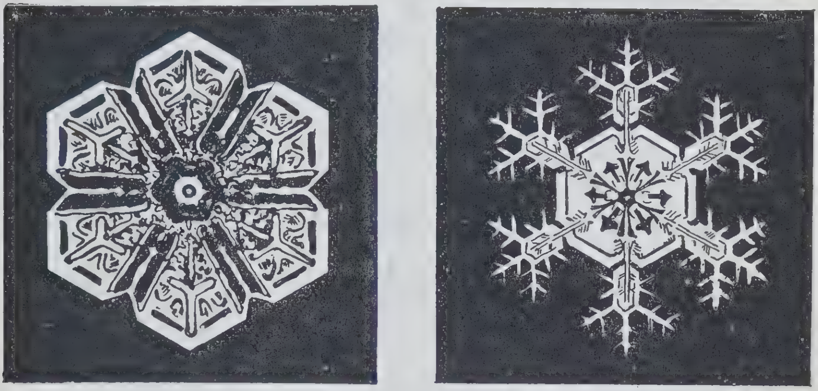


Fig. 106. Snowflakes.

both cases, fine particles of water, which is a liquid, turned to a solid, ice. Each tiny piece of ice has a definite shape. It is called a crystal. Clusters of these crystals produce the patterns found on a window coated with frost. When water commences to solidify on the top of a vessel, you may see a needle-like formation of ice but no definite shapes such as occur in snowflakes. In this case, the moisture is not in finely divided form at the time when it is changing to a solid, with the result that masses of imperfectly formed crystals become crowded together. A block of ice is in reality a mass of crystals imperfect in form.

Water is not the only substance that forms crystals when it turns from a liquid to a solid. Indeed, most substances changing from a liquid to a solid assume a crystalline form. If conditions are favorable, any substance that crystallizes will form into crystals which are similar in shape, although they may be of different sizes (Fig. 107). Precious gems, such as the sapphire, the ruby, the emerald, and the diamond, are beautiful crystals. Some of our minerals are identified by the form of their crystals. In almost any large museum you will find hundreds of wonderful crystals.

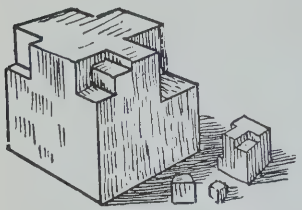


Fig. 107. Crystals of rock salt. What is the difference between the crystals?

In order that you may see crystals forming, perform one or more of the following experiments.

Experiment I

Object.—To obtain crystals of alum.

Apparatus.—Two large test-tubes, a funnel and some filter paper, a string, a small weight, a stirring rod, boiling water, powdered alum (Fig. 108).

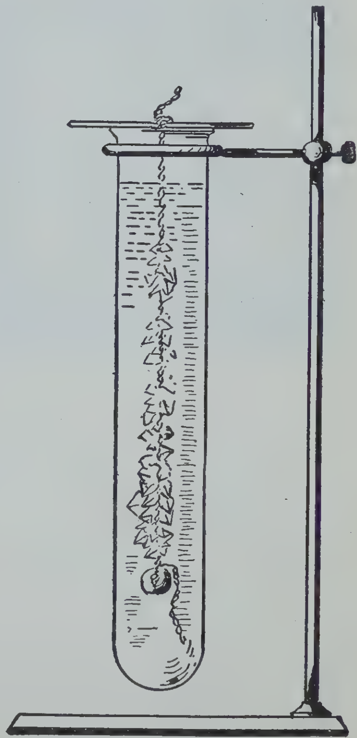


Fig. 108. Crystals of alum.

Method.—Half fill one of the test-tubes with boiling water. Stir into it powdered alum until no more will dissolve and a little of the solid remains in the test-tube. Filter this saturated solution into the clean test-tube to remove any undissolved alum, and suspend in it the string with the little weight tied at the end to hold it still. Allow the solution to remain undisturbed for about an hour or until crystals have formed. Remove the string, loaded with crystals, and examine them with a magnifying glass.

Observations.—(1) Is each crystal separate, or are they massed together? (2) Try to discover the shape of the crystals.

Conclusion.—Is alum a crystalline substance?

NOTE.—If you repeat the above experiment using sugar instead of alum, large clear pieces of *rock candy* will slowly form around the string. Try the experiment at home. Use a tumbler instead of a test-tube. Cover it to exclude dust.

Experiment II

Object.—To obtain crystals of copper sulphate.

Apparatus.—A test-tube, a flat-bottomed dish, such as a saucer, or a large glass evaporating dish, a little powdered copper sulphate, boiling water, a stirring rod.

Method.—Put about an inch of finely powdered copper sulphate in the test-tube, and cover it, to a depth of about four inches, with boiling water. Stir or shake until all the salt has dissolved. Then pour the solution into the flat-bottomed dish, and place it somewhere in the room where it will not be disturbed until all the water has gradually evaporated. Best results will not be obtained unless the dish is kept at some distance from a stove or radiator. Watch for changes from time to time. After all the water has evaporated, examine the contents of the dish with a magnifying glass.

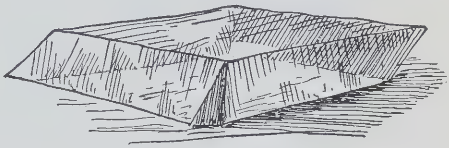


Fig. 109. Crystal of copper sulphate or bluestone.

Observations.—(1) Do both the water and the salt evaporate? (2) When some of the water has evaporated, the part that remains is unable to hold *all* the salt in solution. What happens to part of the salt? (3) Do the crystals *grow*? (4) Are they alike in size? (5) What is their shape (Fig. 109)? (6) Do the crystals around the edge of the vessel grow large, or are they massed together in irregular form?

Conclusions.—(1) Is copper sulphate, like water, a crystalline substance? (2) State one way in which you can bring about crystallization of a substance.

NOTE.—With the knowledge you have gained from this experiment, account for the formation of sugar around the mouth of a syrup jug.

Experiment III

Object.—To form crystals of sulphur.

Apparatus.—Two small beakers, a burner, a little sulphur.

Method.—Fill one of the beakers to a depth of about two inches with sulphur, cover it with a piece of glass, and heat it slowly over wire gauze until all the sulphur has turned to a liquid. Then allow it to cool slowly.

As soon as a firm crust has formed on the top of the sulphur, make a hole in it, and pour out any of the sulphur that is still liquid in form.

Observation.—Do you see long needle-shaped crystals inside the beaker?

Conclusion.—Does liquid sulphur form crystals when it cools and solidifies? Compare this with the behavior of water when it is cooled to freezing point.

When do crystals form?—1. When a strong hot solution is allowed to cool, part of the dissolved substance will crystallize out. With few exceptions, a liquid, such as water, can dissolve more of a solid when it is hot than when it is cold. Consequently, in the experiment in which you saturated some *hot* water with alum, the water could not hold all of the alum in solution when it cooled. Particles of solid alum, therefore, crystallized out of the solution, and became attached to the string. These particles attracted more of the alum, as cooling continued, and these drew still more. Thus the alum crystals gradually "grew" or became built up, as the water cooled.

2. Crystallization will also take place when a liquid in which a substance is dissolved is allowed to evaporate slowly until there is not enough liquid left to hold in solution all the substance that it contains. This condition occurred in the second experiment recorded above. At first, the water was not saturated, and therefore was able to hold all the copper sulphate in solution; but, when some of the water had evaporated, the contained salt was more than sufficient to saturate the remaining water. Consequently, part of the salt came out of solution and formed into tiny crystals. As evaporation continued, more and more of the salt crystallized out and was attracted to these crystals, thus enlarging them.

3. Again we have seen that a liquid may crystallize when it cools to a temperature at which it solidifies or freezes. The liquid sulphur turned to solid needle-shaped crystals

while it was still quite hot. Water, on the other hand, does not solidify or freeze into crystals until it is cooled to 32°F. Crystallization of water may take place in the air. Air always contains more or less moisture. When the air becomes sufficiently cold, some of the moisture crystallizes out. Up in the clouds it forms either snow crystals or hail. On objects on the earth's surface, such as fences, boards, or blades of grass, it forms hoar frost crystals.

Imperfect crystals.—A body of water, on solidifying, forms a mass of imperfect crystals. We call this mass ice. Similarly, when bodies of other liquids change to solid, a great number of crystals, imperfect in form, become massed together (Fig. 110). You saw this occur when the water evaporated around the edge of the dish containing a solution of copper sulphate (Experiment II, page 135). Many rocks are solids of this nature.

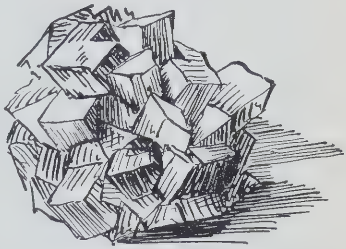


Fig. 110. Crystals of Iceland spar massed together.

Review Outline

(1) Give several examples of crystals formed in nature. (2) You have observed snowflakes that fell on your sleeve. How many points or sides had they? (3) Are crystals of the same substance all alike in size? Do they seem to grow? (4) Crystals form under different conditions. Compare the conditions under which you get crystals of alum with those under which you get crystals of sulphur or ice. (5) Are some crystals imperfect? (6) Account for the difference between snow and ice.

CHAPTER XVI

ICE TO WATER

In studying the behavior of water when it cools and changes to solid ice, you found that the water contracted as it cooled to almost 39°F. or 4°C., but that it expanded as it cooled below that temperature and turned to ice. How does it behave when it changes back to water and heats up again?

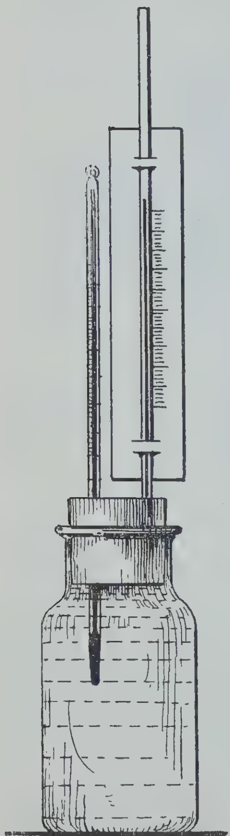


Fig. 111.

Experiment

Object.—To find out how ice behaves when it changes to water, and heats to room temperature.

Apparatus.—Same as in Figure 103.

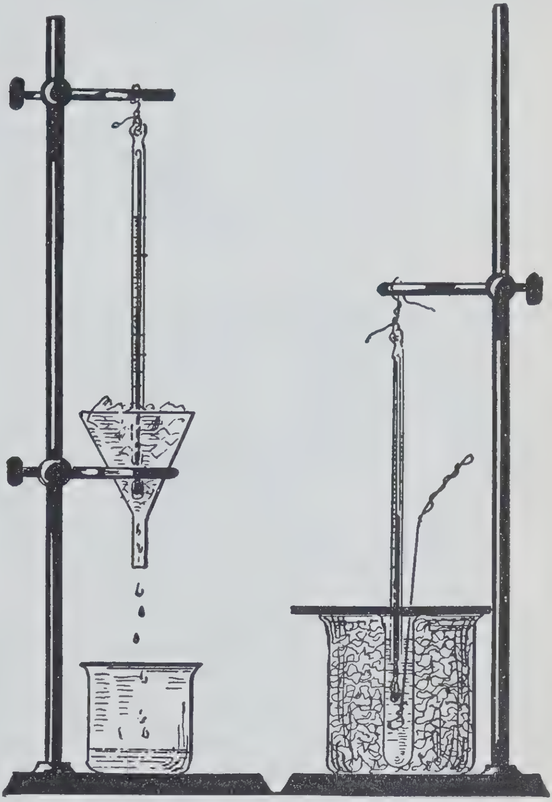
Method.—Freeze the water in the bottle in the manner described in the experiment on page 127, until the water is forced high up in the tube. Mark on the paper scale the height of the water in the tube. Remove the apparatus shown in Figure 111 from the freezing mixture. Notice at what temperature the ice is completely melted, and mark the height of the water in the long tube at the same time. Now keep a record of the height of the water in the tube as the temperature of the water rises degree by degree to room temperature.

Observations.—(1) Does the water in the tube lower as the ice melts? (2) At what temperature does the water contract to its least volume? (3) At what temperature does the water commence to expand? (4) Above this temperature does it continue to expand?

Conclusion.—What change in volume takes place as solid ice changes to a liquid, water, and heats up?

When ice on our lakes, ponds, and rivers melts in the spring, it contracts, turning to water at about 32°F. or

0°C. As the temperature of this water rises to 39°F. or 4°C., it continues to contract, and, being heavier at this temperature per cubic foot than at any other temperature, will sink to the bottom of the body of water, if the water there is either warmer or colder than this temperature. In time the temperature of the whole body of water will become about 39°F. or 4°C. As the surface water becomes heated above this temperature, it will expand and, being lighter than the water below, will now tend to remain at the top. This explains why the water at the bottom of a lake is cooler than the surface water. During the summer, of course, owing to currents caused by winds and running water, the upper warmer water will tend to become stirred with the colder water beneath, thus raising the temperature of the whole body of water.


A Fig. 112. B

Comparison of Melting and Freezing Points

Object.—To find out whether the freezing temperature of water and the melting temperature of ice are the same.

Apparatus.—A funnel (a small can with a few holes in the bottom of it will do), snow or powdered ice, a test-tube, a beaker, salt, a thermometer, a stand, pure water, a piece of wire bent so as to make a small loop on the end for a stirring rod, a piece of cardboard for a lid.

Method A.—Place the test-tube nearly filled with water in the freezing mixture as shown in Figure 112, B. Insert into the water the thermometer and the stirring rod made of wire. Cover both test-tube and beaker with a cardboard with two holes in it, through which the thermometer and stirring rod may protrude. Stir the water constantly and notice the temperature at which the water freezes.

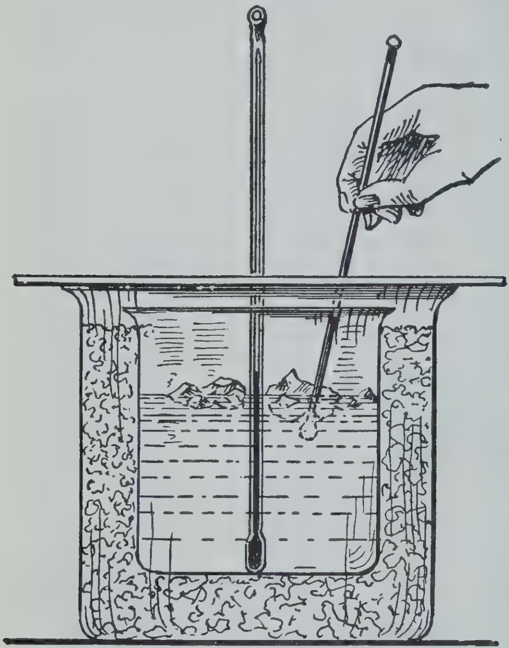


Fig. 113. Why is the temperature of the water in the beaker uniform? Would it be uniform in a lake in which ice is melting?

Method B.—Suspend the same thermometer in the funnel or can that contains melting ice (Fig. 112, A), and leave it there till the liquid in the thermometer becomes stationary. Take the reading.

Observations.—(1) What is the temperature of the water in the test-tube when it freezes? (2) What is the temperature of melting ice?

Conclusion.—Are the melting point of ice and the freezing point of water the same?

What change is there in the temperature of water in which ice is melting?

Object.—To find out whether the temperature of water in which ice is floating is the same as that of melting ice.

Apparatus and materials.—A large and a small beaker, sawdust or felt, pure water, ice, a stirring rod, cardboard for a lid (Fig. 113).

Method.—Place one beaker inside the other with sawdust or felt or other insulating material between them to keep out the heat of the room. Fill the inner beaker one-quarter full of pure water, and add a few pieces

of ice. Cover the two beakers with a lid having two holes in it. Stir the water, observing the temperature from time to time. Add more ice if the first melts. Continue stirring till the temperature as shown by the thermometer becomes stationary.

Observations.—(1) Does the temperature of the water change at first? (2) What is the lowest temperature recorded? (3) Does the water remain at this temperature as long as ice is kept in the water? (4) Is this temperature the same as that of melting ice as recorded in the previous experiment?

Conclusions.—(1) Why does ice cause the temperature of the water to become lowered at first? (2) Why does the water in the beaker remain at a low temperature? (3) What happens to the temperature of water in which ice is floating?

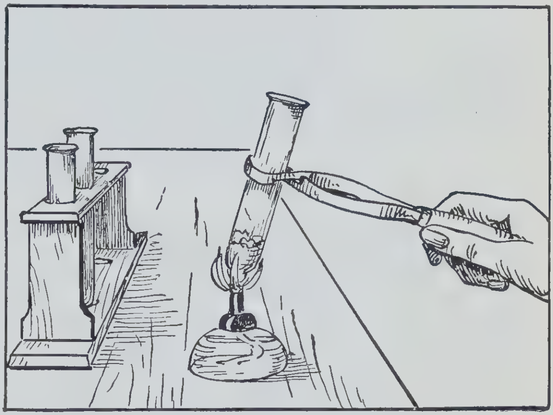


Fig. 114. What do the test-tubes contain? Which substance melts or fuses at the lowest temperature?

Solids to liquids.—Ice is a solid. When it is heated sufficiently, it turns to water, which is a liquid. Above 32°F., water is never in the form of a solid. There are, however, many substances which are solid in form above that temperature. Look about you and name a few of them. Have you ever wondered whether these substances, which are in the form of solids at ordinary room temperature, may turn to liquids at still higher temperatures, just as ice turns to a liquid when heated?

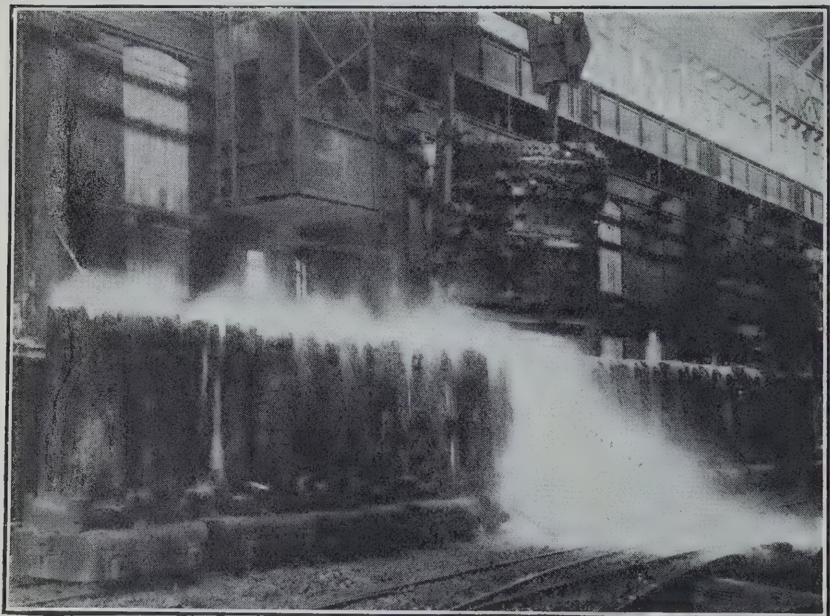
Experiment

Object.—To discover whether some substances which are solids at ordinary temperatures turn to liquids at higher temperatures.

Apparatus and materials.—Three test-tubes, a test-tube holder, sulphur, potassium chlorate, paraffin, a burner (Fig. 114).

Method.—Place a little of each of the substances in separate test-tubes and heat them one by one for some time.

Observations.—(1) Does each substance turn to a liquid when its temperature is raised sufficiently? (2) Do some of the substances seem to change to a liquid, that is, melt, at a lower temperature than others? Use your thermometer to find at what temperature the paraffin melts. Do not use it in the sulphur and potassium chlorate. These would break it.



Courtesy Department of Interior, Ottawa.

Fig. 115. "Pouring" hot metal in Sydney Mills, Sydney, Nova Scotia. The cast iron that is used in school desks and in many parts of machinery melts to a liquid at a temperature of about 2000° F.

Conclusions.—(1) Is ice the only solid that changes to a liquid when its temperature is raised? (2) Does the temperature at which a solid changes to a liquid seem to vary with different substances (Fig. 115)?

Question Outline

(1) What solids used for food can you think of that turn to a liquid when heated? (2) If all solids turned to a liquid at the same temperature as ice does, could you exist in this climate? (3) Give three advantages to you of the fact that iron does not turn to liquid except at a very high

temperature. (4) Ice has a definite temperature at which it turns to a liquid. Is this true of other solids?

Review Outline

(1) The temperatures at which ice melts and water freezes are the same. How did you find out for yourself that this is true? (2) What changes tend to take place in the temperature of water in which ice is floating? Explain why the ice melts and the temperature of the water is lowered. How can you demonstrate the extent of the change? (3) Do all solids change to liquids at the same temperature? What would you use in an experiment to show that your statement is correct?

CHAPTER XVII

EVAPORATION

We have all seen clothes hanging on the line to dry. What becomes of the water? Will the clothes dry more quickly on a warm, dry, sunny day than on a cool, damp, cloudy day? Explain. Will they dry in the winter time when the water in the clothes is frozen? Do clothes dry more quickly in a warm room than in a cool room? If the weather suddenly turns cold, what becomes of icicles left hanging from the eaves? A kettle left on the stove will sometimes boil dry. Does the water still exist? Will a path or a sidewalk dry more rapidly in the warm sun than in the shade?

When water is exposed to the air, it tends to disappear gradually. We say that it "evaporates." The water, which is visible, changes into an invisible gas, called water vapor, and disappears into the air, which is also a gas, or rather a mixture of gases.

The effect of temperature upon the evaporation of water into the air.—You have probably learned from experience the answers to some of the questions suggested above. Let us now find more exact answers by performing three experiments.

Experiment I

Object.—To discover whether temperature affects the rate of evaporation.

Apparatus.—Two large beakers, a little water, a teaspoon.

Method.—Put one teaspoonful of water in one beaker and an equal amount in the other. Place one of the beakers in a *warm* place and the other in a *cool* place. Observe each daily.

Observations.—(1) From which beaker does the water evaporate more rapidly? (2) How long does it take each to evaporate?

Conclusion.—What is the effect of temperature upon the rate of evaporation of a liquid such as water?

Experiment II

Object.—To discover whether temperature affects the rate of evaporation of water.

Apparatus.—A small piece of cloth cut into two equal parts, some water. (The weather must be cold enough to freeze water in order to perform this experiment.)

Method.—Soak the two pieces of cloth in water. Then lift them out of the water without wringing them. Hang one piece of cloth on a line in a warm room, and hang the other on a line out-of-doors where the water in it will freeze. Examine each piece of cloth from time to time to find out how long it takes to dry. The cloth outside will become stiff at first because the water in it will change to solid ice. Later it will become limp, showing that the ice has disappeared, leaving the cloth dry.

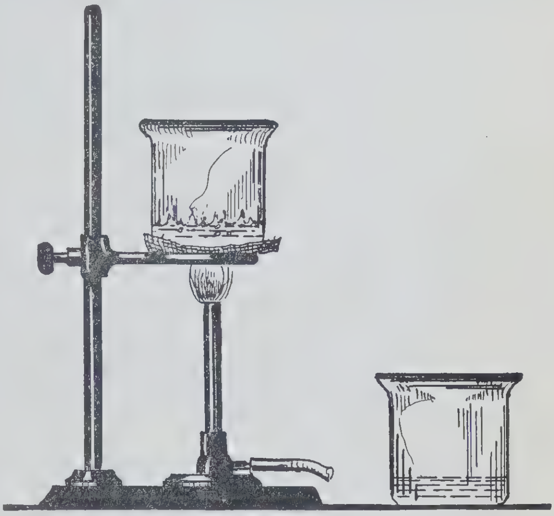


Fig. 116.

Observation.— Which piece of cloth takes the longer to dry?

Conclusions.—(1) Does temperature affect the rate of evaporation? (2) Will water in the form of ice evaporate? (3) Does evaporation take place even at low temperatures?

Experiment III

Object.—To discover whether temperature affects the rate of evaporation.

Apparatus.—Two beakers with about half an inch of water at the same temperature in each, a burner, a stand (Fig. 116).

Method.—Raise the temperature of the water in one of the beakers by heating it until the water boils briskly. Continue the heating for about

five minutes longer. Compare the amount of water remaining in one beaker, with that in the other beaker.

Observation.—In which beaker has evaporation taken place more quickly?

Conclusion.—Does temperature influence the rate of evaporation of a liquid?

Evaporation is the passing off into the air of a solid or liquid, in the form of a vapor or gas. It takes place more rapidly at a high temperature than at a low temperature. At all times, even in places where it is winter, moisture continues to evaporate from the surface of the earth. When the air is warm and the sun is shining, a great quantity of water evaporates, not only from the surfaces of oceans, lakes, rivers, streams, and ponds, but from the surfaces of soil, rocks, and plants. Because this moisture is passing into the air, there is more or less invisible water vapor present in the air at all times.

Cooling effect of evaporation.—Put a few drops of alcohol, gasoline, or ether on the back of your hand. Does it feel cold? Repeat, and fan or blow on your hand to hasten the evaporation. Does this produce a greater sensation of cold? Does the liquid evaporate quickly? The heat required for the evaporation comes partly from the surrounding air, and partly from the hand itself, thereby producing a cooling effect.

We know that, when water is sprinkled on the floor of a room on a hot day, the air of the room becomes cooled as the water evaporates. (Some of the heat in the air is used up in changing the water into an invisible vapor or gas,) just as heat is required to evaporate water from a kettle or beaker. Also we have all noticed the cooling effect produced by a shower of rain on a warm day. The air becomes cooled as heat is absorbed from it to evaporate some of the moisture that has fallen. From these instances we can see that *evaporation is a cooling process.* Can we

not also see how this fact explains why evaporation takes place rapidly at high temperatures? Is it not that, since heat is used up to bring about evaporation, the higher the temperature, the greater will be the rate of evaporation?

Question Outline

(1) How could you show that temperature affects the rate of evaporation of moisture into the air? (2) Does evaporation take place in the winter time? How could you prove your answer? (3) Why does water sprinkled on the floor on a hot day cause the room to become cooler? (4) If a bottle or can of milk is wrapped in a wet cloth and placed in a breeze, it will be kept cool. Explain.

CHAPTER XVIII

RECOVERY OF WATER VAPOR FROM THE AIR

(1) Why do people's glasses become covered with moisture when they enter a warm house on a frosty day? (2) When a kettle has been boiling for some time in a kitchen on a cool day, why do the windows become covered with moisture? (3) How do you explain the formation of clouds of steam when a door is opened on a frosty day? (4) Does dew fall? (5) Whence does it come? (6) Why do we not have dew every summer's evening? (7) Can you account for the formation of drops of water on the outside of cold water pipes at times? (8) Why can we sometimes "see our breath"? (9) Where do the clouds come from? (10) What is a fog? (11) Why does a fog usually disappear as the day grows warm?

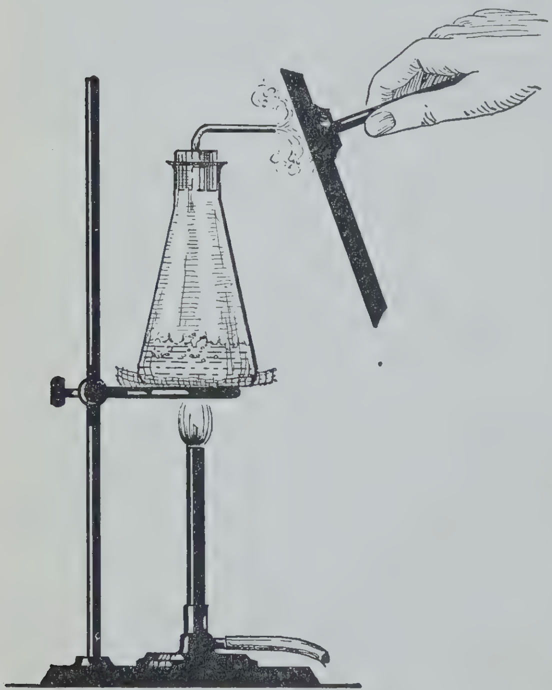


Fig. 117.

We have learned that water is continually evaporating into the air, becoming an invisible vapor or gas. We might now ask: "Can moisture be recovered again from the air?" Let us answer our own question.

Experiment I

Object.—To evaporate water and recover it again.

Apparatus.—A flask with a one-holed stopper and a short bent glass

tube (a tea-kettle will serve equally well), water, a burner, a stand, a piece of cold metal (any cold metal object will serve).

Method.—Set up the apparatus as shown in the diagram (Fig. 117). When the water is boiling briskly, hold the piece of cold metal close to the point where the invisible water vapor or steam is escaping.

Observations.—(1) Can you see the water vapor above the boiling water in the flask? (2) Can you see the water vapor at the point where it is leaving the glass tube? (3) Does water collect on the metal when held in the invisible water vapor? (4) Will the boiling water continue to turn to vapor as rapidly when the burner is removed?

Conclusions.—(1) Can invisible water vapor escaping into the air be recovered again? (2) What is necessary to cause the water to evaporate rapidly? (3) Why is a *cold* piece of metal necessary to change the water vapor back to water?

The heat which is applied to boil the water in this experiment is used up in changing the water to a vapor. If this heat is taken from the vapor, it will be forced to return to the form of a liquid again. The cold metal used in your experiment absorbs heat from some of the escaping water vapor, causing it *to condense*, that is, change from a vapor to a liquid.

Some of the water vapor that escaped from the flask during the experiment was quickly recovered when it was brought into contact with the cold surface of a piece of iron. This fact suggests to us the possibility that water vapor may be recovered from the air by allowing air to come in contact with the surface of a cold object.

Experiment II

Object.—To recover some of the water vapor from the air and produce *dew.*

Apparatus.—Two beakers half filled with water that has been standing in the room for some time, snow or crushed ice, two wooden stirring rods, a thermometer (Fig. 118).

Method.—After wiping the outside of each beaker thoroughly to remove all traces of moisture, half fill each with water that has been standing in the room for some time. Record the temperature of the water. Place the beakers a few feet apart. Stir the water in each beaker, and add a little snow or crushed ice to the contents of one of the beakers. As this

melts, observe closely to see if any change occurs on the outside of each beaker. If no change occurs before the snow or ice melts, stir in more of it till a change is noticed. Then take the temperature of the iced water immediately.

Observations.—(1) What formed on the outside of the cold beaker? Did any moisture appear on the outside of the other beaker? (2) What was the temperature of the water in the cold beaker (*a*) before ice was added, (*b*) at the moment moisture commenced to form on the outside of the beaker?

Conclusions.—(1) What would the cold sides of the beaker absorb from the layer of air and water vapor surrounding it? (2) What is the effect upon the temperature of the surrounding air and the water vapor contained in it? (3) Where did the thin film of moisture that formed on the outside of the beaker come from? This condensed water vapor is called dew. (4) Since the layer of air surrounding the beaker is cooled to the temperature of the water in the beaker, what is the point, as shown by your thermometer, at which moisture condenses on the surface of the cold beaker? (5) What is one way of recovering water from the air? (6) Which will hold more water vapor, warm air or cold air?

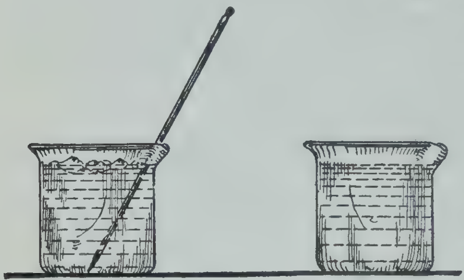


Fig. 118. The air which is around the beakers is at room temperature and contains invisible water vapor. What is the effect of the ice-cold water upon the surrounding air?

Condensation of water vapor on the surface of cold objects. Dew.—Air always contains more or less water vapor. When warm air containing considerable water vapor is cooled sufficiently, part of the water vapor will condense. We therefore say that warm air will hold more water vapor than cold air. In the last experiment, the warm air of the room, on coming in contact with the ice-cold beaker, became cooled to such an extent that it could not continue to hold all of the water vapor that was in it. Part of it, therefore, condensed on the sides of the beaker, forming tiny droplets.

On wash-day you may have noticed tiny droplets of water formed on the cold walls and windows of the room.

During the washing, much water vapor passes into the air. When this air, laden with invisible water vapor, comes in contact with the cold windows and walls, it becomes cooled, and part of the vapor in it condenses into visible drops of moisture on their cold surfaces.

People who wear glasses are always inconvenienced when they enter a warm building in the winter time because moisture collects on the glasses. The warm air of the room, on coming in contact with the cold surfaces of the glasses, becomes cooled, causing some of the water vapor contained in the air to condense on the glasses as tiny droplets, which interfere with the vision.

In the evening the surface of the earth cools more quickly than the air above it. This tends to cool the layer of air which is in close contact with the earth and small objects, such as leaves and blades of grass, upon its surface. If this air contains considerable water vapor, it will not be capable of holding all of it when cooled. Part of it will therefore condense and collect in droplets on cold surfaces, forming *dew*.

Fog or mist.—When a deep layer of air resting on the surface of the earth is cooled, part of its water vapor may condense on the surface of dust particles in the air. Have you ever seen the dust particles in a sunbeam? These numerous particles, each coated with a layer of visible moisture, produce a *fog* or *mist*.

Clouds.—When a layer of air far above the surface of the earth is cooled, part of the water vapor that it contains may condense on the numerous dust particles floating in it, and form clouds (Fig. 119). If moisture condenses in the clouds at a temperature below freezing, it forms into crystals which we call snowflakes.

Rainfall and snowfall.—The moisture that condenses into clouds eventually falls to the earth in the form of rain or snow. Anyone who has watered a garden or lawn with

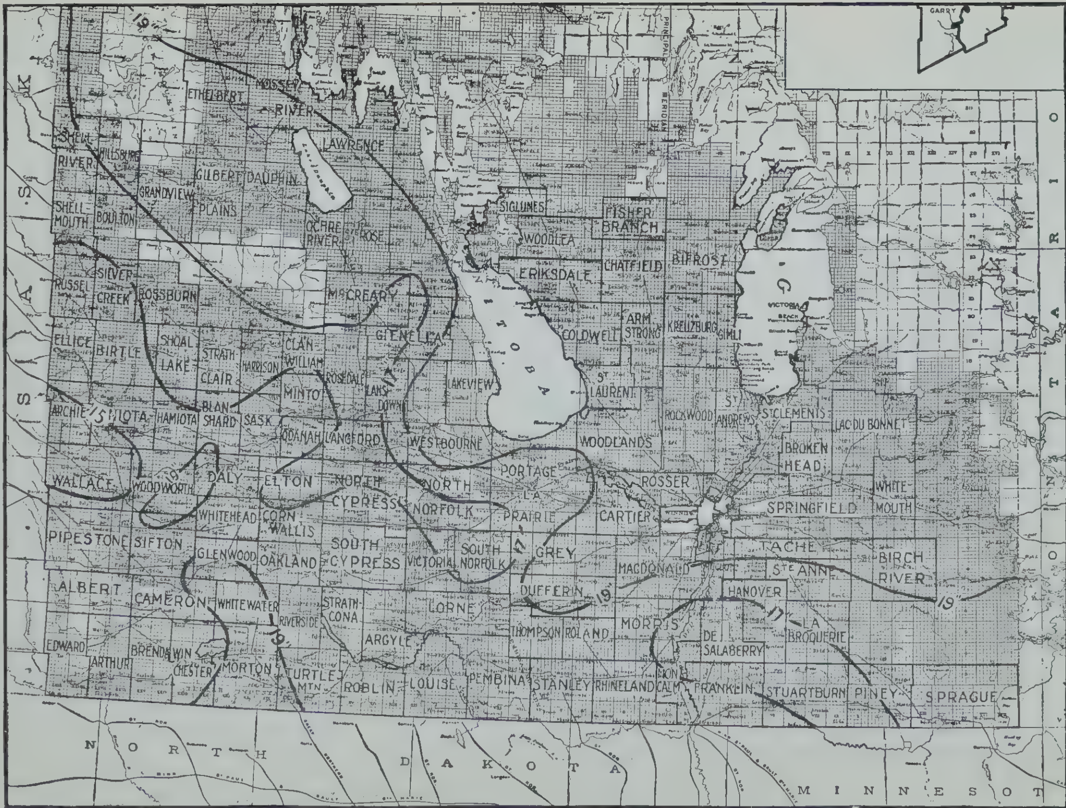
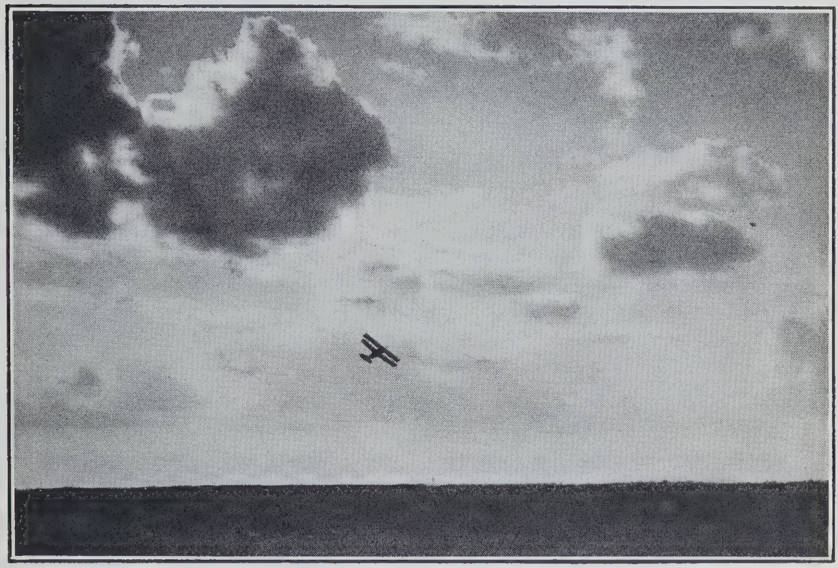


Fig. 120. Map showing average rainfall in Southern Manitoba. Within the 19″ line the rainfall is about 19 inches annually. Within the 17″ line it is about 17 inches. Between these lines it is about 18 inches. Within the 15″ line it is about 15 inches. What is the rainfall where you live?

a hose, or carried water from a pump to the garden, will realize what a hopeless task it would be to water a whole field of grain in this way. During one season an acre of growing grain can use over 900 barrels of water. At this rate, one section of land alone would require 576,000 barrels of water. These figures may help us to realize the enormous



Courtesy H. A. Steel.

Fig. 119. Clouds.

quantity of water that condenses in the air and falls, watering the earth.

The amount of precipitation varies in different places. Over the southern half of Manitoba, sufficient moisture falls, in the form of rain and snow, to cover the ground to an average depth of about eighteen inches annually. In British Columbia the average annual precipitation varies greatly, ranging from about 10 inches in some places to nearly 100 inches in others. At certain places on the earth there is as much as 40 feet of precipitation.

Problems

(1) A 40-gallon barrel holds about 6½ cubic feet of water. Calculate the average number of barrels of water that falls annually on a section of land in one of the rainfall areas shown on the map on page 152. (2) If you live within the area shown on the map, find the depth of precipitation in your district. How much water would fall on a garden 70 yards square (approximately one acre) in your district? (3) At Prince Rupert the average annual rainfall is about 103 inches. How many barrels of moisture fall on an acre of land in that city annually?

Review Outline

(1) How can you recover some of the water escaping from a kettle or a flask of boiling water? (2) How can you demonstrate how dew is formed? How is it formed in nature? (3) What is fog or mist? (4) Account for clouds. (5) What is the origin of rain and snow? Notice the importance of rain and snow for watering the land. If we received no rain or snow for a year, could our crops grow? What is the cause of a famine?

CHAPTER XIX

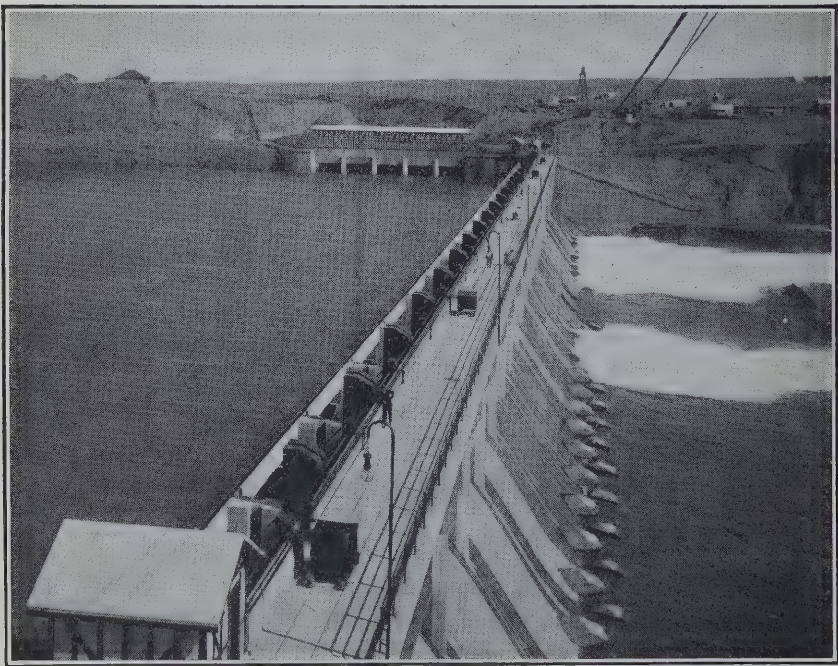
GREAT MOVEMENTS OF WATER

Have you ever wondered what becomes of all the rain and snow? Water that falls to the earth may do one of three things: (1) It may *run off* along the surface of the ground. (2) It may *evaporate* into the air. (3) It may *soak into the ground.* Let us consider each of these possibilities.

Fig. 121. How the run-off water of the prairies reaches the sea. Most of the run-off water in the southern part of the three Prairie Provinces collects in streams, rivers, and lakes. Eventually much of it reaches the sea at the mouth of the Nelson River. What main rivers drain this vast southern area? From a geography find what carries off the surplus water of the northern parts of these provinces. Into what oceans does the water run? Does all the water that enters these streams reach the sea? How does some of it get back to the land from the sea?

1. Run-off water.—Some of the rain falls more rapidly than it can soak into the ground. This water runs away in

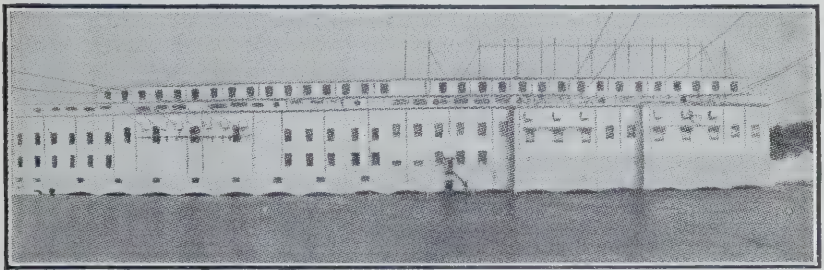
Fig. 122. A flood. The run-off water caused the river to overflow its banks.



Courtesy Canadian Pacific Railway.

Fig. 123. The Bassano Dam in Alberta. The dam holds back some of the run-off water flowing in the river so that it may be used to irrigate land. It is allowed to flow slowly out through the gates into the irrigation canal. Some water escapes through the dam. This ensures that the people living along the river below it will not be without water.

little streams. These may empty into low places, forming ponds, or collect into larger streams, forming rivers, which may broaden into lakes. Eventually a great deal of this water reaches the sea (Fig. 121). It is this run-off water that causes floods at times, resulting in damage to life and property (Fig. 122). Man sometimes stores part of this run-off water and uses it for irrigation purposes (Fig. 123). In some places, the run-off water is harnessed and made to drive water wheels and turbines to develop electricity that can be used for power and for lighting purposes (Fig. 124).



Courtesy Winnipeg Hydro Electric System.

Fig. 124. City of Winnipeg Hydro Electric System Power House, Pointe du Bois. Run-off water is being used in this plant to produce electricity. Water from behind the dam flows through turbines or water wheels that turn electric generators.

When moisture falls in the form of snow, it must melt before it can run off. On many high mountains, however, the temperature is so low for most of the year that only part of the snow that falls each year melts. Consequently, great masses of it accumulate. Owing partly to the effect of alternately thawing and freezing, and partly to the tremendous weight of the top layers of this snow, much of the mass becomes changed into solid ice, forming glaciers (Fig. 125). These move slowly down into the valleys below, melt, and run off in streams.

2. Evaporation of rain and snow into the air.—The moisture that falls to the earth, watering the land, forming rivers and lakes, and running into the sea, is continually

evaporating into the air again. The amount of water that evaporates from the ground, from the surfaces of leaves, and from bodies of water, such as oceans, lakes, and streams, is tremendous.

A single large weed can use a barrel of water in a season. Most of this water is evaporated into the air from the leaves of the plant. We have learned that an acre of crop will use

Courtesy Canadian Pacific Railway.
Fig. 125. Lake of Hanging Glaciers, Alberta.

as much as 900 barrels of water. Most of this is evaporated. These two instances help us to realize how great is the amount of water evaporated from the surfaces of leaves alone. What must be the total evaporation from all sources in a district or a province? Bear in mind also the fact that, while much evaporates from the land, over three-fourths of the water that passes into the air comes from the surface of the oceans, and you will see that, by evaporation, most of the rain and snow water is eventually returned again to

the air as vapor. High up in the air this vapor is carried from place to place by winds, forms clouds, and returns once again to the earth as rain and snow.

3. The rain and snow water that sinks into the ground.—Much of the rain and some of the snow water soaks into the ground. The amount that sinks into the ground depends upon several factors. If the rainfall is heavy, much of the water will tend to run off before it has time to go down into the ground. You have seen this happen after a downpour of rain. On the other hand, most of the water that falls in a gentle rain sinks into the earth. Loose ground and ground covered with vegetation absorb water much more readily than hard or frozen lands. Floods result in the spring when the snow melts quickly but cannot sink into the hard, frozen earth. On sloping land, water tends to run off more readily than on flat surfaces. Some soils absorb water more rapidly than others.

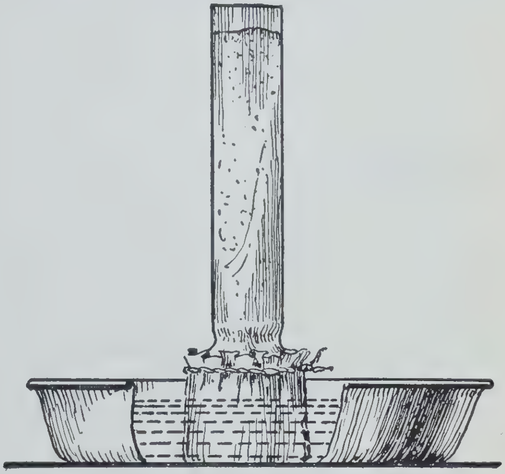


Fig. 126. Will water rise through the sand in the lamp chimney?

What becomes of the water that sinks into the ground?—1. Some of the water that sinks into the ground returns again to the surface and evaporates. To understand how this is possible perform the following experiments.

Experiment I

Object.—To show how ground water returns to the surface.

Apparatus.—A lamp chimney, dry sand or soil, a flat dish or pan, a small piece of thin cloth, water (Fig. 126).

Method.—Tie the piece of cloth over the end of the lamp chimney. Then fill the chimney with dry sand or soil, place it in water in the flat pan or dish, and allow it to stand.

Fig. 127.

Observation.—Does the water rise through the sand or soil?

Conclusion.—Does water rise through the tiny spaces or pores in the sand or soil?

Experiment II

Object.—To show how ground water returns to the surface.

Apparatus.—A piece of cheesecloth about two feet long and one foot wide (a piece of moistened lamp wick may be used instead), a beaker, a stand, ink or other coloring material (Fig. 127).

Method.—Fill the beaker to a depth of one or two inches with water, and add some coloring so that you may observe more easily what happens. Roll the cheesecloth and then twist it, making a wick about two feet long. Support one end of the wick by the stand, allowing the other end to hang down into the colored water. Allow the apparatus to stand for some time.

Observation.—Does the water rise in the wick or cloth?

Conclusion.—Will water rise through the tiny spaces in a wick or cloth?

NOTE.—The same result will be seen if you put the end of a blotter in water or ink, or if you hang a rough towel from the edge of a pail with one end of the towel resting in water. Oil rises through the wick in a lantern or lamp in the same way.

Much of the ground water gradually returns to the surface again. The water rises through the spaces between the fine particles of soil in the same way that it rises in a blotter or wick (Fig. 128). At the surface this moisture is either absorbed by plants and finally evaporated from their leaves, or evaporated from the surface of the ground. Without the water thus brought to the surface, all our plants would die during the summer.

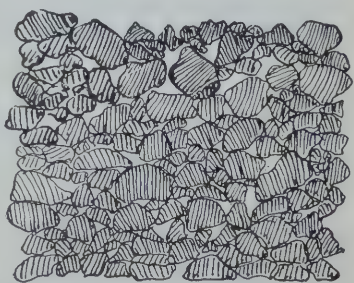


Fig. 128. Diagram of particles of soil with spaces between them.

2. A part of the ground water returns to the surface in *springs, artesian wells,* and *wells.*

Soil is made up of more or less finely divided particles. Part of the rain and snow water that sinks into the ground adheres to the surface of these particles, and part of it slowly sinks down through the spaces between them. In time it reaches layers of clay or rock through which it can scarcely pass. There it tends to collect, fills up the spaces

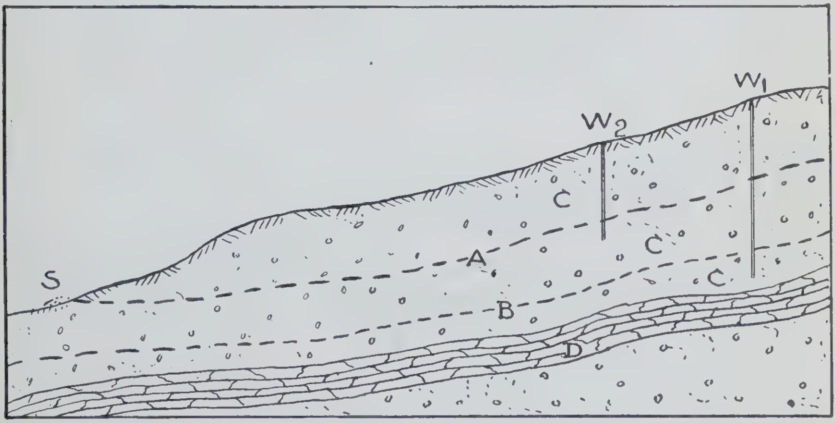


Fig. 129. A, Water table during wet season. B, Water table during dry season. C, Soil and sand and gravel which is porous. D, Impervious layer of rock or clay. S, Spring. W_1 and W_2, Wells. Why does the well marked W_1 contain water all the year around, while the one marked W_2 does not? Will the spring flow continuously?

between the soil particles, and stands at a certain level known as the *water table* (Fig. 129).

The water table varies from time to time and from place to place. During wet seasons this water level, or water table, rises nearer to the surface of the ground than in dry seasons. If it rises above the surface of the ground at any point, water will run out, forming a "spring." As impervious rock[1] or soil stands at different depths below the surface of the ground, the water table is lower in some places than

[1]Impervious rock or clay is rock or clay that is not porous and will not allow water to soak through it to any extent.

in others. Ground water lying along a sloping bed of impervious rock or clay gradually runs from higher to lower levels, *slowly* draining away some of the stored ground water. This lowers the water table. In this way the water table may lower a great deal during a dry season.

Artesian wells.—In many places the earth's crust is partly made up of layers of different kinds of rocks. Some of these layers are porous and will allow water to sink into them readily, while others are impervious to water. Where the earth's crust has wrinkled or folded, it sometimes happens

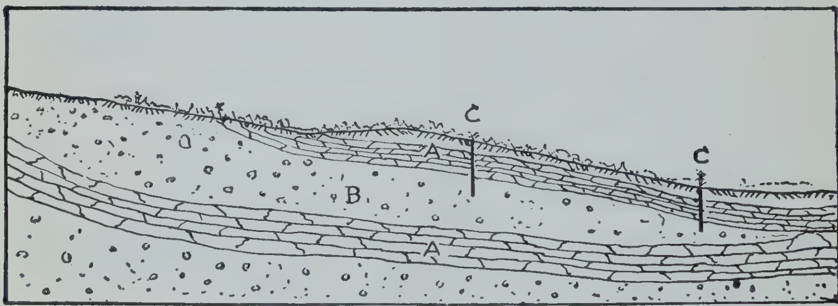


Fig. 130. A, Impervious layer. B, Porous layer. C, Artesian wells. Why does water gush up higher at one well than at the other?

that the edges of layers of rock have come to the surface (Fig. 130). If one of these layers is porous and lies between two impervious layers, the ground water will sink into it and become entrapped. When these layers are inclined or sloping, as shown in the diagram, much ground water may become stored as the porous layer becomes saturated with water. In the lower levels this water will be under the pressure of the weight of all the water above it. A hole, drilled down through the impervious layer lying above the stored water, will allow it to escape. If the water is under considerable pressure, it may gush out of the hole, forming an *artesian well*.

Artesian wells are quite common in certain areas. At

one time, Winnipeg got much of its water from such wells, but so much was required that the store of underground water became used up, the wells ceased to flow, and then the water had to be pumped out. In the state of South Dakota there are over 1000 artesian wells in one area, some of which give out from 1000 to 3000 gallons of water per minute. Anyone who has visited Gimli, Manitoba, will have seen the artesian wells located there. At this place, a hole is drilled to a depth of about 100 feet through an impervious layer into

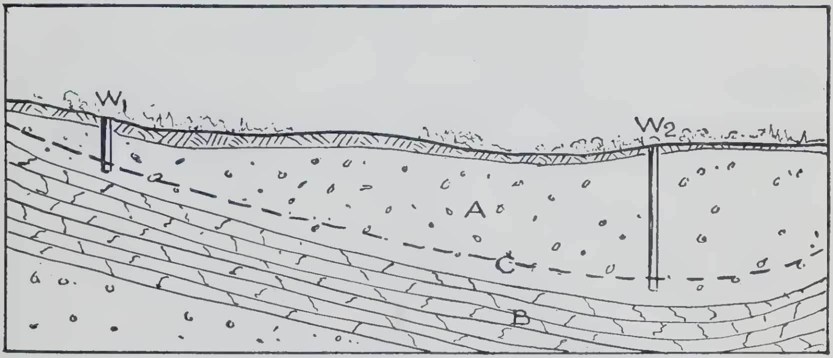


Fig. 131. W1, Shallow well. W2, Deep well. A, Porous layer. B, Impervious layer of rock or clay. C, Water table in dry season. Account for the difference in depth of the two wells.

a layer of gravel containing stored ground water. The water gushes out of these holes and continues to run summer and winter. This layer of gravel comes to the surface many many miles back from Gimli at a higher level. At this point, ground water soaks into the porous gravel and finds its way to lower levels of this sloping layer, filling it up with water which cannot escape because of the impervious layers above and below it. The weight of the stored water at the higher levels, resting upon the water in the layer at lower levels, exerts considerable pressure. This causes the water to gush out when a hole is bored down to the store of entrapped water. For drinking purposes,

this water is healthful, being absolutely free from surface contamination.

Wells.—If a well is dug sufficiently deep to go below the water table, some of the free water standing between the soil particles will run into it. When the water table is far below the surface of the ground, a deep well is necessary. One farmer may get plenty of water by digging a fifteen-foot well, while another may have to dig forty feet or more

Fig. 132. The water cycle. Water evaporates, rising from the river and the surface of the soil. It forms clouds, which drift in the wind. Eventually the water falls again to the earth as rain or snow, completing the cycle.

(Fig. 131). In deserts, where there is little rainfall, the water table may be hundreds of feet below the surface, making it difficult to obtain any well water.

Summary showing where ground water goes.—We have seen that some of the ground water gradually comes back to the surface of the earth again, in the same way that oil rises in a wick and is evaporated. We have learned that some of it may reach the surface and escape from springs. Some of it may be pumped out. Part of it may gradually run away underground, but at lower levels much of this comes to the surface again. Lastly, a little of the ground

water is continually sinking deep into the earth. Even rock is not absolutely impervious to water, for we have reached no depth at which water is not found. It is estimated that enough water has soaked into the earth to cover the whole of its surface to a depth of over 800 feet.

The water cycle.—Water comes from the air to the surface of the earth in the forms of dew, rain, and snow. Part of it quickly evaporates back into the air. Part of it runs along the surface of the ground, forming streams and bodies of water. From these it continually evaporates back into the air. Part of it sinks into the ground, but eventually most of the ground water returns to the surface and evaporates back into the air (Fig. 132). The water that evaporates back into the air from so many sources forms clouds, which are carried by the wind from place to place. From the clouds the water returns again to the surface of the earth. Thus we see that the great mass of water of the earth moves in a cycle, being continually evaporated from the earth into the air and again falling upon its surface.

Review Outline

(1) What three things may happen to the rain that falls upon the earth? Does the same apply to melting snow? (2) What is "run-off water"? What uses do we make of it? Give examples. (3) Account for glaciers. How could they form the head-waters of streams? (4) Account for the great amount of moisture found in the air. (5) What is "ground water"? Give conditions under which (*a*) little water and (*b*) much water may sink into the ground. (6) Describe an experiment to show how ground water returns to the surface. (7) What is a "water table"? What is the relation between a water table and a spring? a water table and a well? (8) What is an artesian well? What is the difference between an artesian well and a spring? (9) To what level must you dig to get a well in which you will have water the year round? (10) What is the "water cycle"?

CHAPTER XX

WATER AS A SOLVENT

What takes place when a spoonful of sugar disappears in a glass of water? How could you find out whether a glass of clear well water is pure? What is the "scale" that forms on the inside of a kettle? How does water become "hard"?

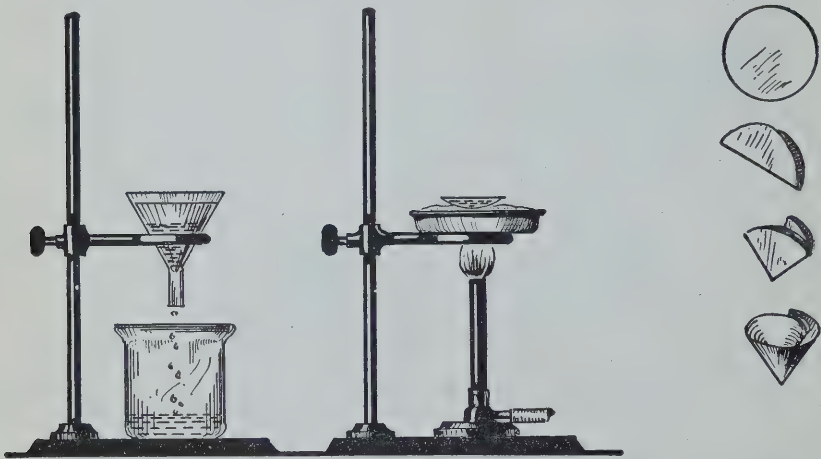


Fig. 133. How is the filter paper folded? Why is a dish of sand or soil placed under the watch crystal?

Are all substances that disappear in water equally soluble? Suggest some uses of water as a solvent.

Experiment

Object.—To examine the nature of a mixture of a salt, such as common salt, and water.

Apparatus.—Two clean beakers, a stirring rod, a funnel, a piece of filter paper, a burner, a watch crystal or a small beaker, clean water, a little common salt (use dairy salt), a flat dish containing sand (Fig. 133).

Method.—Fill one of the beakers with water and stir into it a teaspoonful of the salt. When the salt has completely dissolved, taste the mixture. Then pour about half of it into the other beaker and taste what remains. Try to remove the salt from the water by pouring some of the mixture through the filter paper placed in the funnel. Then pour a little of it into the watch crystal or small beaker and slowly evaporate the water. Protect the crystal or beaker from cracking by putting between it and the flame the flat dish containing sand or powdered earth to a depth of about one inch. Taste what remains.

Observations.—(1) Can you see the *salt* after it has dissolved? (2) How do you know that it is still in the water? (3) Does the salt separate from the water when stirring is discontinued? (4) Does the salt evaporate with the water?

Conclusions.—(1) When a solid like salt dissolves in water, does it mix thoroughly? (2) Does the solid break up into divisions that are so small that they cannot be seen in the water? (3) Does a substance remain dissolved or does it quickly separate again?

NOTE.—Another salt, such as alum, may be used instead of common dairy salt.

A solution.—When a substance dissolves in water, it tends to mix thoroughly, forming a clear even mixture called a *solution.* A substance that dissolves another substance is called a *solvent.* To look at a solution of salt and water, or sugar and water, one cannot distinguish it from pure water. The dissolved material cannot be removed by filtering; but, if the water is evaporated, the solid may be recovered again.

Is rain water free from dissolved substances? Is it pure after it runs over the earth or sinks into it?—We cannot tell by looking at a glass of water whether it contains any materials (salts) dissolved in it; but, if we evaporate the water, the salts will remain in the dish. Knowing this, let us try to find out whether the natural waters found upon the earth, such as rain water, river water, and well water, contain any dissolved salts in them.

Experiment I

Object.—To discover whether our "natural waters" contain dissolved materials.

Apparatus.—Watch crystals or small beakers from which water may be evaporated, one or more burners, one or more flat metal dishes containing sand (lids of tin pails are very satisfactory for holding the sand), samples of distilled water, rain or snow water, creek or river water, lake water, well water, and sea water if possible (Fig. 134).

Fig. 134.

Method.—Put equal amounts (about fifteen drops, or a teaspoonful) of the several samples of water in different watch glasses or beakers. Slowly evaporate the water in each, taking care to insert a flat metal dish, containing sand, between the glass and the burner. Examine each vessel after the water has evaporated.

Observations.—(1) Does the water contain dissolved material in each case? (2) List the various samples of water according to the amount of salt that they contain. (3) Does distilled water contain any dissolved materials (salts)?

Conclusions. — (1) Does water that falls as rain and runs over or through the ground contain dissolved materials (salts)? (2) What kind of water is free from dissolved salt? (3) What natural water do you find contains (*a*) the least salt, (*b*) the most salt.

NOTE.—(*a*) Account for the formation of a coating or scale on the inside of a kettle or boiler (Fig. 135). (*b*) Account for the fact that rain is necessary to enable plants to grow in soil.

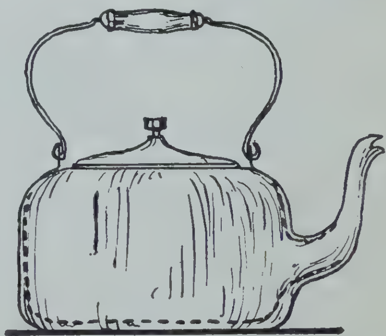


Fig. 135. What is the origin of the scale or "fur" on the inside of the teakettle?

Experiment II

Object.—To discover whether rain water that runs through soil dissolves part of it.

Apparatus.—A can large enough to hold a quart or two of soil, enough earth to fill the can, rain water, a beaker, a funnel and a piece of filter

paper, two stands, two watch crystals (two beakers will do), a flat dish containing sand, a burner (Fig. 136). (Do not use melted snow in place of rain water for this experiment unless the snow is fresh and clean.)

Method.—Punch a few holes near the centre of the bottom of the can. Almost fill it with earth. Then support it on a stand, as shown in the diagram. Place beneath it the funnel. Fold the piece of filter paper properly and insert it in the funnel. (The filter is required to catch any solid earth that may wash through the holes in the can.) Under the funnel set the beaker.

Put about fifteen drops of the rain water into one of the watch crystals or beakers; then slowly pour rain water into the can of earth until about half a beaker of it escapes through the holes in the bottom of the can, passes through the filter paper, and is collected in the beaker underneath. Now put about fifteen drops of this water into the other watch crystal or beaker.

Completely evaporate both samples of water over sand placed above the burner. Then compare the amount of solid material found in each watch crystal or beaker.

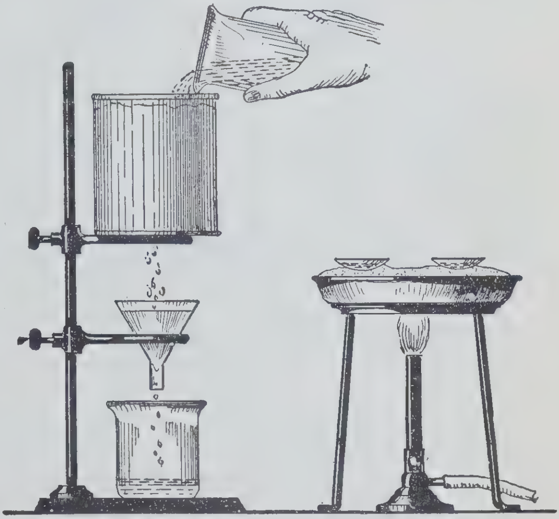


Fig. 136. What is the purpose of the filter?

Observations. — (1) Can you see any dissolved material in the two samples of water before evaporating them? (2) Does the water contain dissolved materials in each case? (3) Which sample of water contains the more dissolved materials (salts)?

Conclusions.—(1) Does water that falls as rain contain some dissolved materials (salts)? (2) Does this water dissolve still more salt as it sinks down through soil? (3) Explain why well water contains more dissolved salts than rain water.

Water found on the surface of the earth is never absolutely pure. As it falls to the earth, dust particles, suspended in

the air, become caught in the rain drops. Running over the surface of the ground, it dissolves various salts from the surface soil and carries these away. When it sinks into the earth, it dissolves even more soil materials. Rain water is our purest natural water because it has come in contact with very little soluble material. The waters of streams and lakes contain more dissolved salts than rain, but they have not dissolved as much material as the water that slowly soaks through the ground and finds its way into wells. This is because they do not come into such close contact with the soil.

Hard and soft water.—We have found that it is possible to discover many things for ourselves by means of experiments. Let us now try by this means to discover what is meant by "hard" and "soft" water.

Experiment

Object.—To find out what we mean by "hard" and "soft" water.

Apparatus.—A wash basin, a pint of well water and an equal amount of rain water (snow water will do), a cake of soap.

Method.—Put the well water in the basin. Then rub a little soap on your hands and try to wash them in the water. Repeat the operation using the rain water.

Observations.—(1) Is it "hard" to rub the hands together when the well water is used? (2) Does the rain water feel "soft" or slippery when the hands are rubbed together? (3) In which case does a lather form the better on your hands?

Conclusions.—(1) In which kind of water is it "hard" to wash? (2) In which kind of water is it hard to produce a lather with soap? (3) Which water feels "hard" or harsh, and which feels "soft" or slippery, when used with a little soap?

Natural waters, which contain a considerable amount of dissolved salts, will not produce a lather unless a large quantity of soap is used. Such waters are called "hard." Well water is a good example of hard water. On the other hand, natural waters which contain very little dissolved

materials easily produce a lather with very little soap. These waters are considered "soft." Rain water is an example of soft water. Hard water can be softened by the addition of much soap or some washing soda. Boiling also aids in the softening of water by causing some of the salts that have been dissolved in it to collect on the sides of the kettle or boiler in the form of a scale or "fur" (Fig. 135).

Fig. 137. What is the purpose of the mortar and pestle?

Solubility of various substances.—We have seen that natural waters all contain dissolved substances. As rain comes in contact with the soil, it dissolves substances from it. We may naturally wonder whether the substances with which water comes in contact dissolve to the same extent in it.

Experiment

Object.—To find out whether some substances are more soluble in water than others.

Apparatus.—Three test-tubes, common salt, copper sulphate, chalk (Fig. 137).

Method.—Grind a little of each material to a fine powder. Put the powders into separate test-tubes, filling each to a depth of one inch. Add an equal bulk of water to each test-tube and shake the contents for two minutes. Allow each to settle.

Observation.—Is there the same amount of undissolved material left in each test-tube?

Conclusion.—Are all substances soluble to the same extent in water?

Question Outline

(1) Make a list of the things used by the housekeeper that are soluble in water. (2) Consult a book on agriculture or an encyclopaedia to find out the names of some of the soluble materials of soil. (3) Do you know any soluble materials used as medicine? (4) Are *solids* the only substances that are soluble? (5) Name ten different substances that are practically insoluble. (6) Can you wash oil and grease out of clothes with water alone? (7) What solvents does a painter use?

Water is a great solvent.—Water dissolves more or less of almost every substance with which it comes in contact. It dissolves not only *solids* like sugar, common salt, and substances found in the soil, but also many *liquids* and *gases*. Pour a little liquid, such as alcohol or glycerine, into some water and shake it. You will find that it quickly dissolves. *Gases,* such as air, are soluble to some extent in water. This can be demonstrated by filling a beaker with cold water from the tap or well and slowly heating it. Bubbles of gas collect along the bottom and sides of the beaker. These bubbles cannot be water vapor because they do not disappear immediately when the water is allowed to cool. This gas is air. Cold water will dissolve more air than warm water. When the water is heated, therefore, some of the air that is dissolved in the cold water separates from it and collects as bubbles of gas on the sides of the vessel.

Uses of water as a solvent.—Many uses are made of the solvent power of water. Some of our foods are cooked and partly dissolved in water to render them more digestible. Water that we drink helps to dissolve the food within our

bodies. Before plants can obtain food from the soil, it must be dissolved in the water that soaks into the ground. Without this dissolved food, plants cannot grow. Consequently, drought frequently causes a famine because animals and man depend largely on plants for food. Animals such as fish, that live in the water, require air dissolved in the water to sustain life. Without this air, they would suffocate and die. Of great importance to us is the dissolving

Courtesy Street Commissioner, Winnipeg.

Fig. 138. Power flusher. As the tank is drawn through the streets, water is forced out of it by air pressure to wash away the dirt.

power of water on dirt (Fig. 138). We depend upon water to keep ourselves and our homes clean and healthful.

Insoluble substances.—While many substances are quite soluble in water, some are practically insoluble. Porcelain and glass are used as containers for water because they do not readily dissolve. Sand along the seashore resists the solvent action of the waves. Rocks, such as marble and granite, are used extensively for monuments, not only because of their beauty, but because they do not tend

to dissolve in the rains. Wood, brick, and stone would be of little value as building materials if they were soluble to any extent in water (Fig. 139). Grease and oils, because they are insoluble in water, must be removed from clothing by solvents such as gasoline and household ammonia.

Fig. 139. Stonehenge. These stones were erected so long ago that no one knows who put them there. Rains have washed them for centuries without dissolving them. Why is stone a suitable material of which to construct buildings and bridges?

Review Outline

(1) How could you show the nature of a solution? (2) Does rain water dissolve substances when it comes in contact with them? (3) What is the cause of the coating found on the inside of a kettle? (4) Do all natural waters contain dissolved materials? How could you prove your answer? (5) When is water considered "hard"? Why? What is the difference between "hard" and "soft" water? (6) How can you soften hard water? (7) Are all substances equally soluble? How could you test this? (8) Make a statement of the importance of water as a solvent. (9) Name a few things that are valuable because they are insoluble in water.

CHAPTER XXI

PURIFICATION OF WATER

How can we obtain water free from dissolved substances? How does the sea become salt? Is it safe to drink water that contains salts from the soil? What makes water unfit

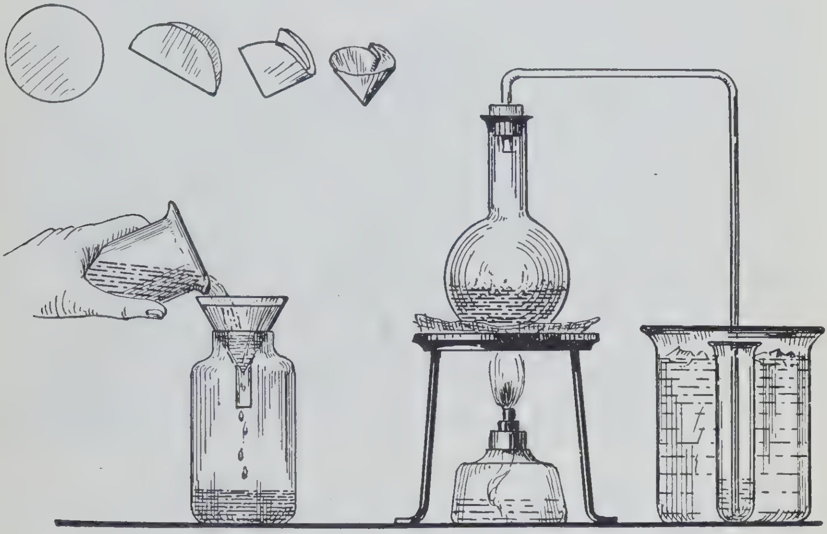


Fig. 140. Which method purifies the water more completely? Why?

for drinking? Since all natural waters contain more or less material dissolved in them, we may wonder how it is possible to obtain pure water.

Experiment

Object.—To show how water may be purified.

Apparatus.—A Florence flask, a test-tube, two beakers, a bottle, a funnel, filter paper, a piece of glass tubing, a one-holed stopper to fit the flask, a spoonful of earth, a little common table salt, water, ice, or snow, a burner (Fig. 140).

Method.—Fill one beaker with water. Put in a teaspoonful each of soil and table salt. Stir thoroughly. Pour one-half of the contents into the funnel with the filter paper in it and arranged as shown in the diagram. Pour the other half of the contents into the Florence flask and set up the apparatus as shown in the diagram, putting the long arm of the glass tube right down to the bottom of a clean test-tube surrounded by cold water, ice, or snow. Heat the water in the Florence flask and allow it to boil slowly away until about an inch of water has collected in the test-tube. Notice the color and the taste of the water in the bottle and in the test-tube.

Courtesy The Greater Winnipeg Water District.

Fig. 141. This photograph shows the building of the great concrete pipe or aqueduct through which the supply of water flows for over ninety miles from Shoal Lake to the city of Winnipeg. Notice that it is horseshoe-shaped and that the walls are thicker near the bottom than at the top. After it was installed, the aqueduct was covered with several feet of earth. Why?

Observations.—(1) Do the soil particles pass through the filter paper? (2) Does the water in the bottle taste salty? (3) Is the water that evaporates from the Florence flask and condenses in the test-tube clear? (4) Does it taste salty?

Conclusions.—(1) Can solids which are in water be removed by filtering? (2) What cannot be removed from the water by filtering? (3) How can we separate solids and dissolved substances from water and thus purify it? Do you know the name given to this process?

Filtering. City water supply. Wells.—When water is filtered, solid substances *suspended* in it are removed,

but the materials that are dissolved in the water escape through the filter with the water.

The water supply for a city or town is usually piped in from some large river or lake.[1] Before this water is distributed by water mains to the factories, homes, and places of business, if there is much solid material suspended in it, it is filtered by passing it through great beds of sand. While this filter removes these impurities, it does not take out any salts dissolved in it. For drinking and cooking purposes, however, it is not necessary to remove these salts because they are of value to us as food.

Besides suspended substances and dissolved salts, water may also contain bacteria, such as disease germs, which are so small that they cannot be seen except through a microscope. For this reason, a chemical such as chlorine, which will kill germs, is added to the water before it is supplied to the city or town.

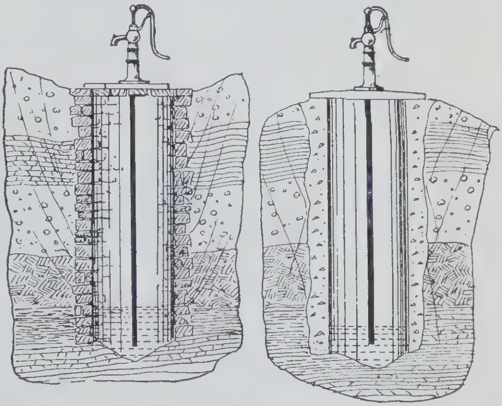


Fig. 142. Diagram of a properly constructed well and a poorly constructed well. What dangers may arise from water leaking into the poorly constructed well?

In the country, the water supply is usually obtained from wells (Fig. 142). The water from a deep well looks clear because it has been filtered. As the dirty muddy water from the surface of the ground soaks down through layers of soil, sand, gravel, and sometimes even rock, particles of soil and other substances suspended in it are filtered out. Some of this cleansed water collects in wells which are dug deep

[1]The water for Winnipeg, for example, is piped in from Shoal Lake, a distance of more than ninety miles (Fig. 141).

enough to reach below the *water table.* Thus the earth is a filter and purifies water for our use.

Although well water is clear and free from suspended substances, we know that it may contain dissolved substances from the air, soil, and rocks, because these cannot be removed by filtering. It may also contain bacteria. Typhoid fever, in many instances, results from drinking well water that has been contaminated with typhoid germs.

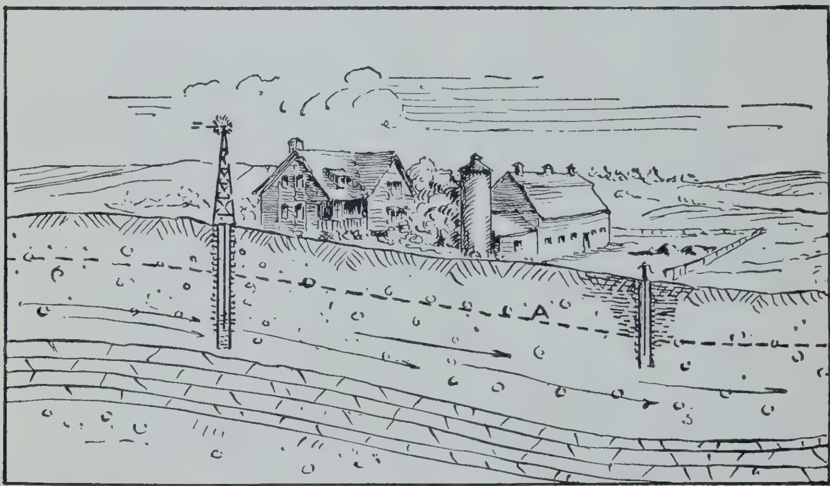


Fig. 143. A, Water table in dry season. Which well is properly located? Why?

Germs, which are in reality tiny one-celled plants or animals, are found in the air, in the soil, and in the water. Since their food is chiefly decaying animal and plant substances, great numbers of them develop in barnyards, outhouses, and places where refuse and sewage are dumped. Water seeps through the ground from these places, carrying with it great numbers of these germs. If a well is dug nearby, it will probably become polluted by this water (Fig. 143). Water from such a well should never be used for drinking purposes before it is boiled.

Distillation.—The process of purifying water by first

evaporating and then *condensing* it is called *distillation* (Fig. 140). When evaporated, the water vapor passes off, but the suspended and dissolved substances remain behind because the heat is not intense enough to vaporize them. When condensed again by being cooled with cold water, ice, or snow, the vapor forms pure water, which may be collected.

Fresh water and salt water.—Distillation on a large scale is constantly going on in nature. Great quantities of water are continually *evaporating* into the air, from water and objects on the surface of the soil, from lakes and streams, and from the seas. In time, most of this water vapor *condenses* again into pure water, and returns to the earth as dew, rain, and snow.

Much of the water from our streams and lakes finally runs into the sea, carrying with it the salts which are dissolved by it while running over and through the land. From the sea this water is continually evaporating into the air, leaving behind all the salts that were dissolved in it. Constant addition of salts to the sea in this way have made it salty.

Unlike the seas, our lakes and streams contain very little salt. This is because water is continually running out of them towards the sea, allowing new or fresh water containing little dissolved salt to enter in its place. Thus we find salt water in the seas and oceans, but fresh water in the streams and lakes.

Review Outline

(1) Is water that looks clear always pure? Give reasons for your answer. (2) How could you purify a sample of water? (3) How are materials suspended in water often removed? (4) Why may the water on the surface of the ground look muddy while the water down in a well nearby may be quite clear? (5) Would it be advisable to drink water from a shallow well? Why? (6) What is a common cause of typhoid fever? To avoid danger from disease, what precautions should be taken when locating and constructing a well? (7) What is the difference between fresh and salt water? Why does this difference exist?

CHAPTER XXII

FACTORS AFFECTING SPRING TEMPERATURES

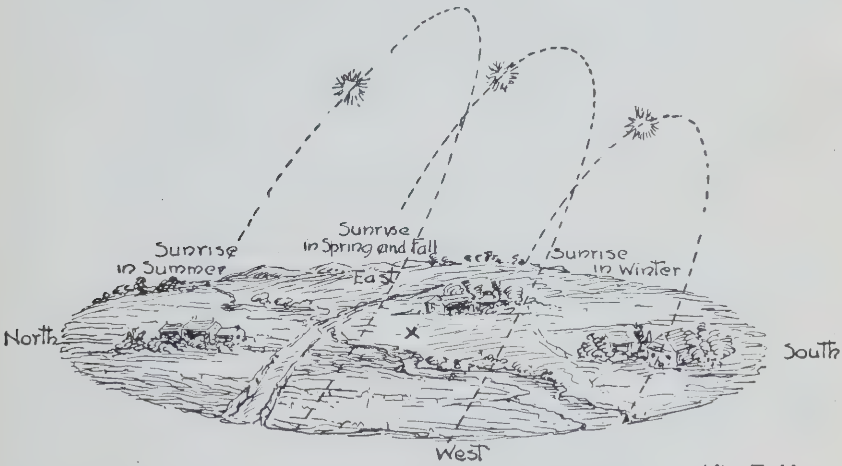
(1) Which is the shortest day in the year? (2) Compare the length of time between sunrise and sunset, at intervals of two weeks for a period of three months following the shortest day. Notice how the hours of sunshine increase. During this period, does the sun rise higher and higher in the sky? The sun is closer to us in winter than in summer. Why are its rays less intense? (3) Why is January usually colder than December, although the days are longer and the sun rises higher? (4) Does the white snow have any effect upon the amount of heat received into the surface of the earth? (5) How does heat get to us from the sun or from a bonfire? (6) How does the sun's heat become absorbed into the earth? (7) When one end of an iron poker is held in the fire why does the other end become hot? Explain. (8) Why do we put wood on the handles of soldering irons, teapots, and kettles? (9) In what way is an aluminium kettle better than an iron one? (10) Why are woollens better than silks to keep us warm? (11) Why do fur and feathers make excellent animal coverings for winter? (12) Which would be better, storm windows or a double thickness of glass? (13) Why do we make hollow walls? (14) Why are white clothes cooler than black ones in summer? (15) From what common sources do we get heat? (16) Show how the heat derived from the burning of wood or coal has its origin in the sun.

I. LENGTH OF DAY. INTENSITY OF SUN'S RAYS. SNOW

In the chapter on *Temperature* it was pointed out that during the fall and early winter the days grow shorter and the path of the sun in the sky shifts steadily to the south. From observations made since the time of studying that chapter, you have no doubt learned that about Christmas time the days begin to grow longer, that the positions of sunrise and sunset are moving northward, and that the sun is daily rising higher in the sky. The average temperature,

however, instead of rising immediately, continues to become lower for some time before it rises again.

During the summer, when the sun, which is our great source of heat, rises high in the sky and the days are long, the part of the earth in which we live, and bodies of water around us, absorb much more heat by day than is given off again during the day and night (Fig. 144). In this way a



After Todd.

Fig. 144. This diagram shows the path that the sun appears to follow across the sky at the various seasons of the year. Notice the directions of sunrise and sunset as seen by a person standing at X. (To show the proper noon position as seen from X the circles would require to be enormously enlarged.) Is more of the sun's path above the horizon in summer than in winter? Compare the length of day for the various seasons.

great deal of the sun's heat becomes stored in the earth, in rocks, and in water.

In the autumn and during the first part of the winter, however, we get fewer and fewer hours of sunshine because the days are gradually growing shorter. Moreover, the heat from the sun becomes steadily less intense (Fig. 145). In consequence, the amount of heat absorbed by the earth and water about us at this time of year becomes much decreased. At the same time, heat continues to escape from them and is lost.

By the time winter sets in, the amount of heat that we are receiving from the sun is less than that being lost by the land. Less heat results in lowered temperatures. Long after Christmas, indeed during January and much of February and March, although the days are growing longer, and the number of hours of sunshine is gradually increasing, the amount of heat being lost by the earth is still greater than that gained, thus causing the weather to remain cold.

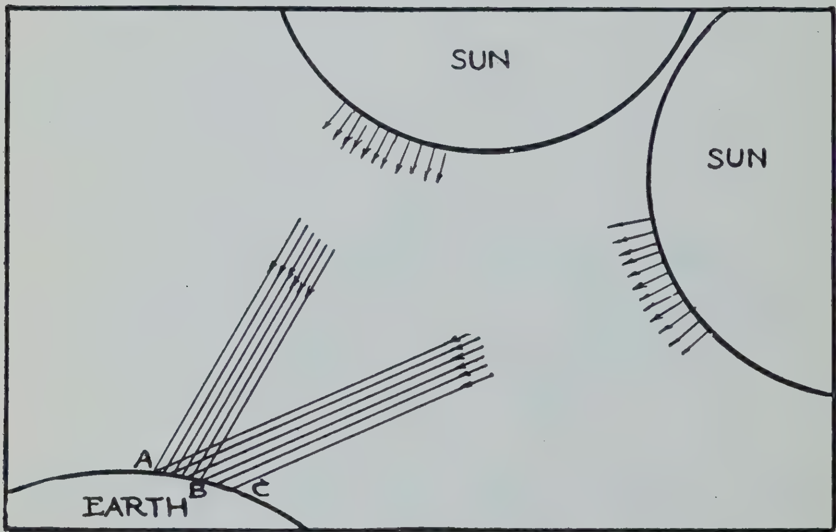


Fig. 145. Diagram showing beams of heat and light rays of equal width coming from the sun to the earth when the noon sun rises nearly overhead as in summer, and when it remains lower in the southern sky as in winter. Compare the extent of surface of earth heated by the same number of rays—in summer, A to B; in winter, A to C. Does each square foot of surface receive more heat rays in summer or in winter?

In the spring, when the length of the days greatly increases, giving us many more hours of sunshine, and the rays of the sun become more intense, the amount of heat absorbed by the earth and water around us during the day becomes more than that lost at night. In consequence, we experience warmer weather, or higher temperatures.

What effect has snow upon winter temperatures?—During the summer and part of the spring and fall, the

surface of the earth and water is dark in color. During the winter, when the snow lies on the ground, the surface is white. Does this difference in color affect in any way the amount of heat received from the sun? To answer this question perform the following experiments.

Experiment I

Object.—To find out whether the sun has the same heating effect on white surfaces as on black.

Apparatus.—Two small pieces of cloth of equal thickness, one white and the other black, snow, two flat dishes such as saucers (Fig. 146).

Method.—Lightly compress about two tablespoonfuls of snow into a little ball and place it in one of the shallow dishes. Cover it with the piece of white cloth. Lightly compress an equal amount of snow and put it in the other dish. Cover this with the piece of black or dark-colored cloth. Place both dishes in bright sunlight. Use a window of a room that is fairly cool, otherwise the heat of the room will melt the snow. If it is not freezing out-of-doors, you may place the dishes on the window ledge outside.

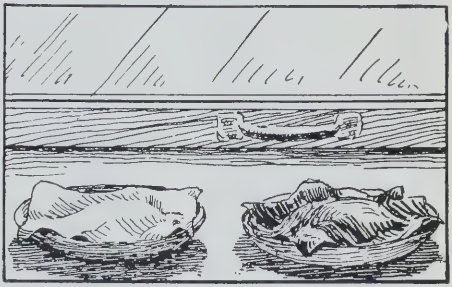


Fig. 146. One dish is covered with a black cloth, the other with a white cloth. Under which cloth will the snow melt more quickly?

Observation. — Under which piece of cloth, the white or the black, does the snow melt more rapidly?

Conclusions.—(1) Which absorbs heat from the sun more rapidly, a light-colored or a dark-colored object? (2) Which would absorb more heat, the dark earth or white snow?

Note.—While this experiment is being performed indoors, repeat it out-of-doors, varying the method by placing two pieces of cloth, about the size of a handkerchief, one white and the other dark-colored or black, on some level snow outside. The day should be mild and sunny. Leave the cloth on the snow for several hours. Which piece of cloth sinks into the snow? What conclusions do you draw?

Experiment II

Object.—To find out whether the sun has the same heating effect on a white or light surface as on a black.

Apparatus.—Two tall cans, small in diameter, with shiny surfaces, two pieces of cloth, one white and the other black, a candle, water, two thermometers, two stands (Fig. 147).

Method.—Hold one of the cans in a candle flame until it becomes coated black over its entire outer surface. If the candle has heated the can somewhat, allow it to cool. Then almost fill each can with water of the same temperature as the room. Tie a piece of black cloth over the top of the black can, and a piece of white cloth over the other. Make a slit in each piece of cloth, and put a thermometer through each slit, down into the cans of water. Mount each can on a stand and place them in a closed window through which the sun is shining brightly. Observe the temperature of the water in each can from time to time.

Observations.—(1) What change in temperature is observed in each can during a period of one or two hours? (2) Does the temperature of the water in each can rise to the same extent under the influence of the heat rays of the sun?

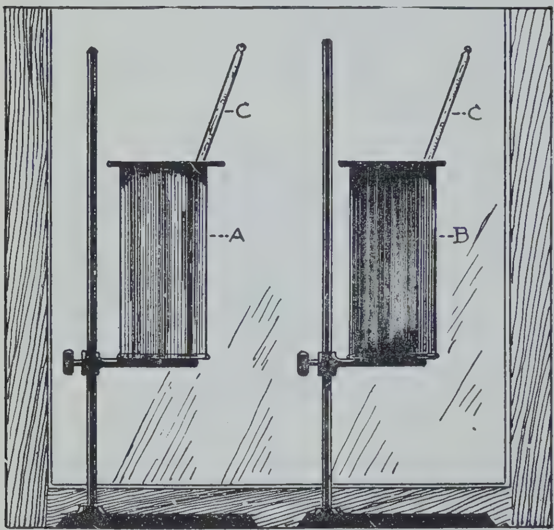


Fig. 147. A, Can with shiny surface and full of water. B, Can with blackened surface and full of water. C, Thermometer.

Conclusions. — (1) Which absorbs heat the better, a dark or a light surface? (2) Do you think that some of the heat rays coming from the sun may be reflected from the white surface in the same way that rays of light are reflected from a shiny or white surface? If so, these would give no heat to the water within. (3) Does the rough blackened surface reflect light rays? If it reflects heat rays no better than light rays, can you account for the fact that the water in the blackened can heats more quickly than that in the can with the shiny surface?

Thought questions.—(1) A market gardener sometimes throws soot on the snow covering his garden land in the spring to get rid of the snow. Explain. (2) Snow melts most quickly in the spring around bare spots of earth. Account for this. If you wished to have your house cool in summer, would it be better to put black paint on the shingles of the roof, or to cover them with paint or stain of a lighter color?

The results of these experiments would lead us to believe that a black surface absorbs heat from the sun better than a white one. The explanation of this is easily understood when we realize that heat comes to us from the sun in the form of heat rays, just as light comes to us in the form of light rays. When these rays of heat and light, which are travelling at the amazing rate of 186,000 miles per second, strike the surfaces of objects which are white or light in color, many of them are reflected off these surfaces, and but little heat enters the light-colored objects. On the other hand, when these rays strike the surfaces of dark-colored or black objects, much heat and light becomes absorbed by these objects.

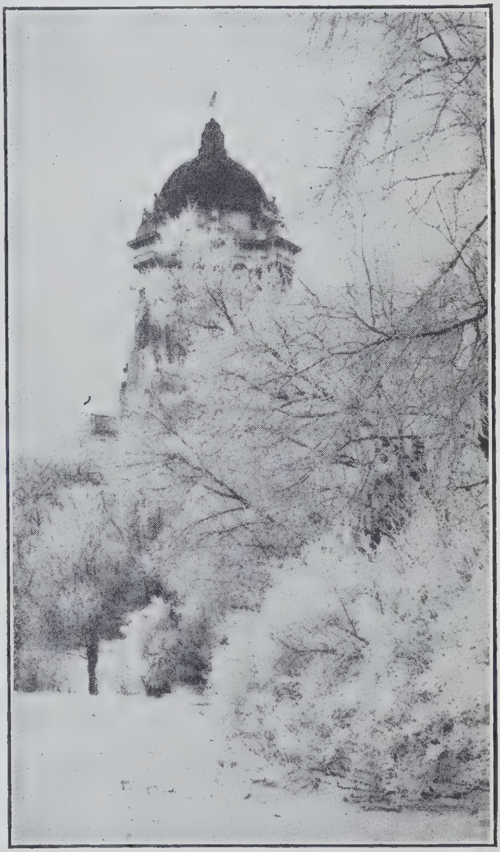


Fig. 148. Mantled in snow. What is the effect of the white snow on winter temperature?

Let us now return to the question asked at the beginning of this section: "What effect has snow upon winter temperatures?" Can you suggest an answer? It is no doubt clear to you now that, during the winter months, much heat from the sun, coming to us in the form of heat rays, becomes reflected from the white surface of

the snow, just as light becomes reflected from the snow's surface on a bright sunny day, making it very hard for us to open our eyes wide. In the summer, most of the heat coming to us from the sun becomes absorbed into objects that are dark in color. In consequence, summer temperatures are high. In the winter, the opposite effect is produced, because many of the heat rays of the sun become reflected from the white mantle of snow that blankets our land and waters (Fig. 148). This results in low winter temperatures.

The *melting* of the snow has a marked effect upon temperature in the spring. A great deal of heat coming from the sun at this time of year is used up in melting the snow. Snow water is at the same temperature as that of the melting snow. Yet a great deal of heat is required to change the snow to water. The presence of snow on the ground in the spring, therefore, tends to prevent a general rise in temperature at this time of year. When snow is very abundant, the spring is usually long and cool, because much of the sun's heat is absorbed in melting the snow.

Review Outline

(1) State two reasons why temperature decreases greatly during the winter. (2) What experiment could you perform to show that the sun has not the same heating effect on a light as on a dark object? (3) State and explain the effects of snow upon the temperature of our land.

II. CONDUCTION

(1) How does the heat derived from the sun become absorbed into the water, the earth, and objects upon the earth? (2) How is heat transferred from the surface to the interior of a solid object? (3) Do some materials transfer heat better than others? (4) What do we mean by "good conductors" and "poor conductors" of heat?

When the heat rays coming from the sun strike the surface of an object and become changed into heat, we find that some of this heat travels into the interior of the object.

Do all substances conduct heat in this way equally well?

If you have not already done so, grasp one end of a short iron poker and thrust the other end into a fire. You will soon find that the end which you are holding becomes so hot that you cannot retain your hold. The heat must travel along through the metal of the poker. This method of transferring heat is called *conduction.* When you hold a small piece of wood with one end in a fire, little or no heat becomes conducted to your hand, although the end of the stick may be burning. The metal poker is a *good conductor* of heat, while the wood is a very *poor conductor* of heat.

Experiment I

Object.—To test various solids to learn which are good conductors and which are poor conductors of heat.

Apparatus.—A burner or lamp, a piece of copper wire and a piece of iron wire, each six inches long, a glass rod, a wooden splinter six inches in length (Fig. 149).

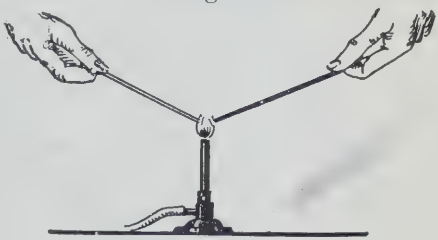


Fig. 149.

Method.—Take the end of the copper wire between the thumb and first finger of your left hand, and the iron wire in a similar way with your right hand. Hold the free end of each wire in the flame of the burner or lamp. When the heat has been conducted along the wire to each hand, cool the iron wire by dipping it in water. Then repeat the experiment using (*a*) the iron wire and the glass rod or tube, (*b*) the copper wire and the wooden splinter. If you can procure fragments of stone, brick, and porcelain (a broken plate or saucer), heat one end of each of these in the same way.

Observations.—(1) Which conducts the heat from the flame to your hand the better, copper wire or iron wire? (2) Are the glass rod, the wooden splinter, brick, stone, and porcelain good or poor conductors of heat?

Conclusions.—(1) Do all substances conduct heat equally well? (2) Which of the solids used in the experiment are good and which are poor conductors of heat?

Prepare answers for the following:—(1) Why do we put wooden handles on teapots, teakettles, and curling tongs? Name other articles on which you find handles partly made of substances that are poor conductors of

heat. (2) Would a hot body, such as a flatiron, cool more rapidly when placed on a metal object or when placed on wood? Explain. (3) Pipes made of iron are used to carry hot water and steam to radiators for heating purposes. Why are these pipes frequently covered with asbestos? (4) Glass is suitable for windows because it admits light. Give another important reason why it is suitable. (5) Of what materials do we construct the walls and roofs of our houses? Are these substances good or poor conductors of heat? Try to discover which material is best, which next, etc.

Experiment II

Object.—To discover whether some metals are better conductors of heat than others.

Apparatus.—A piece of copper wire, a piece of aluminium wire, and a piece of iron wire, each about six inches long and of the same diameter, a cardboard or wooden holder, a burner, a candle (Fig. 150).

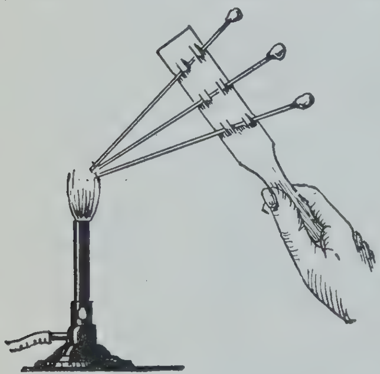


Fig. 150. Why does the wax, placed on the ends of the wire away from the flame, not melt at the same time?

Method.—Attach the three wires to the cardboard or wooden holder, as shown in the diagram. Soften some candle wax by heating it, and stick a little of it on one end of each of the wires. Heat the other ends of the wires with the burner.

Observation.—On which wire does the wax melt first? Which next?

Conclusion.—Are some metals better conductors of heat than others?

Questions.—(1) How does the heat pass from a stove into the water contained in a kettle resting upon it? (2) What materials are used for the making of teakettles? Which do you think are the best? Why?

Experiment III

Object.—To discover whether water is a good or a poor conductor of heat.

Apparatus.—A test-tube almost filled with cold water, a burner (Fig. 151).

Method.—Hold the test-tube of water over the burner, as shown in the diagram. See that the flame strikes the test-tube below the level of the water to prevent breakage. Heat the water till it boils.

Observation.—Does the water in the lower part of the tube remain cold when that in the upper end is boiling hot?

Conclusion.—Is water a good conductor of heat?

NOTE.—Would heat from the sun be conducted very rapidly into a body of water, such as a lake?

How is heat conducted?—All substances whether solids, liquids, or gases, are made up of tiny particles called *molecules*. These particles (molecules) are so small that they cannot be seen even with the help of the most powerful microscope. Molecules are closer together in some substances than in others. In a gas, like air, for example, they are relatively far apart, while in a solid, such as silver or copper, they are quite close together. It is believed that these molecules are all in rapid motion, bouncing off one another as if they were made of rubber.

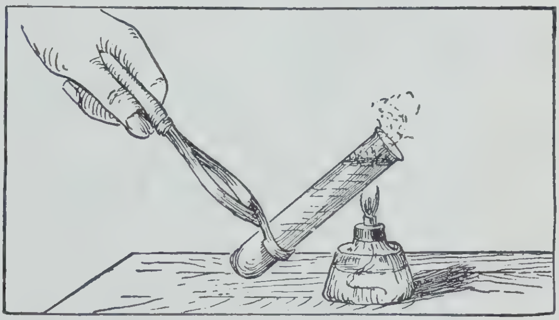


Fig. 151. Why can the water in the upper end of the test-tube be boiling while the other end remains cold?

When a substance is heated, these molecules bounce, or vibrate, faster and harder, but, when it is cooled, the motion decreases. The tiny particles (molecules) at the ends of the wires and other materials used in your last experiments became heated by the flame, thus increasing their motion. As these particles bounced more vigorously, they disturbed the particles next to them, making them bounce more rapidly. These bounced against the particles beyond them, thus transferring or conducting the heat. In this way the heat travelled along from molecule to molecule through the different materials used in the experiments. The molecules in glass, air, and porous

materials are relatively far apart. Would you expect them to be very good conductors of heat?

Some solids are better conductors of heat than others; some scarcely conduct heat at all. Study the following table of common substances arranged in order of their power of conducting heat. Use the figures for comparison.

Silver	100	Tin	14.7	Glass	.2
Copper	74	Granite	.53	Water	.124
Aluminium	35	Limestone	.52	Felt	.008
Brass	27	Ice	.5	Air	.005
Iron	15				

Wash boilers are often made with copper bottoms. Give reasons for this.

Copper is $\frac{74}{100}$ or about $\frac{3}{4}$ as good a conductor as silver. Aluminium conducts heat about half as well as copper. Compare iron with aluminium.

Let us examine a household article and account for the kind of material used in its construction. What kind of metal is in your teakettle? It may be copper, aluminium, iron, or iron coated with enamel or tin. Which of these metals will best conduct heat from the stove to the water in the kettle? Which tarnishes most readily? Iron is cheap, but it is also heavy to handle, easily rusted, and not such a good conductor as either aluminium or copper. In considering which is cheapest and best to buy, one must take into account the cost of labor to keep it clean as well as the cost of fuel necessary to heat the water. While copper is more efficient than aluminium, it tarnishes more easily, and the tarnish is poisonous. In consequence, copper is not in such favor in the kitchen.

Temperature of the earth's crust and its effect upon the temperature of the air.—The outside layers of rock and soil

of the earth make up the earth's crust. Soil, rock, and objects upon them, with the exception of water, are chiefly solids. In general, they are all poor conductors of heat. In consequence, although the total heat received upon the land from the sun's rays in one summer is very great, it is conducted but slowly into the rock and the soil.

During the day the soil and rock quite near the surface of the earth's crust may heat up a few degrees, but at night much of this heat becomes slowly conducted to the surface and lost, as the earth cools again. A little of it, however, remains in the rock and soil. In our part of the earth, in summer, as the days are long and the nights relatively short, a little more heat is conducted down into the earth by day than is conducted back to the surface and lost again by night. A little heat, therefore, accumulates in the earth's crust each twenty-four hours. This heat gradually finds its way deeper and deeper into the earth's crust, as the summer advances. One year, a test taken at a certain point in Canada showed that the increase in temperature of the soil during the whole spring and summer was only about seven degrees at a depth of nine feet below the surface of the earth. At no place on the earth's crust does much heat from the sun penetrate beyond a depth of fifty feet.

Fortunately, although the heat is but slowly conducted into the earth's crust during the summer, it is but slowly conducted back again to the surface. In consequence, the earth's crust does not freeze to a depth of more than a few feet even in our cold winters. Heat stored up in the earth during the summer gradually escapes into the air during the fall and winter and helps, to some extent, to moderate our winter climate. A blanket of snow lying over the earth in winter tends to check the loss of some of the heat stored in the earth's crust. In this we see a further effect of snow upon the temperature of our winter weather.

Water, a poor conductor of heat.—The solids which form the earth's crust are not the only poor conductors of heat. Water, which covers over five-sevenths of the earth's surface, is also a poor conductor. The last experiment that you performed (Fig. 151) showed you this, because you found that, while the water in the top part of your test-tube was boiling hot, the water a short distance below it remained as cold as ever. In consequence, although the surfaces of great bodies of water, such as lakes and oceans, become heated to some extent, the water lying deep below the surface remains quite cold. Of course, currents in the water stir to some extent the warm surface water and mix it with the deeper cold water, thus increasing the depth of warmed water. Heat conducted into the water of our lakes, rivers, and surrounding oceans during the summer is but slowly conducted to the surface of these waters again and given off to the air. In consequence, these waters continue to give off heat to the air above them during the colder months and thus help to moderate our winter temperatures. Ice on the surface of any of these bodies of water also hinders the loss of heat, because it is such a poor conductor of heat. (See table, page 190.)

Air, a poor conductor of heat.—While many solids and liquids, including water, are poor conductors of heat, air is a still poorer conductor. Dry, dead air (that is, dry air that is not moving) is one of the poorest conductors of heat. As we shall see, we make use of this fact in the construction of our homes and many useful articles.

How are houses made warm? — In a cold climate, houses should be built from such materials and in such a way that the heat produced in a house by the burning of fuel cannot be easily conducted through the walls and roof and lost. For this reason non-conductors of heat are used in their construction. Wood, brick, paper, asbestos,

wood-pulp boards, flax straw, strawboards, gypsum, concrete, plaster, stone, and glass are some of the materials used for this purpose. With the exception of glass, all these materials are porous. In the pores, or minute openings, is dead air, which makes these substances even better non-conductors. To provide additional dead air spaces, walls are constructed with hollows or spaces in them (Fig. 152). Find out what you can about the structure of the house in which you live.

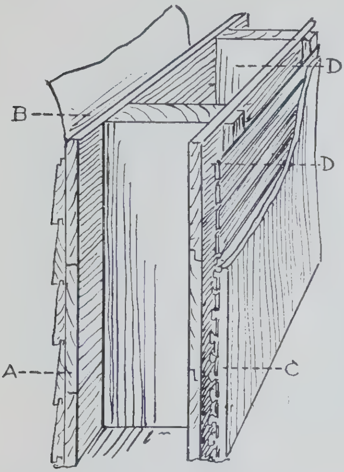


Fig. 152. Section of a wall. A, Boards. B, Paper. C, Plaster. D, Dead air spaces. How many layers of non-conducting material are there in this wall?

Although glass is a very poor conductor of heat, it is made so thin that, in the winter time, a good deal of heat is conducted away through it. To prevent this loss, storm windows are put on our buildings in winter. A storm window not only provides a double thickness of glass but also forms a dead air space between the inner and the outer windows. Storm windows should fit tightly; otherwise the air between them and the inside windows will stir about and carry with it some of the heat from the inside to the outside windows, through which it will be conducted away and lost Storm doors not only pro-

Fig. 153. Polar bear. Why is the fur so long? Is it waterproof?

vide additional layers of wood to keep in heat but also form dead air spaces between the outer and the inner doors. Closely-fitting window blinds, pulled down to the bottoms of windows, prevent the loss of much heat. Explain.

Fur. Feathers. Clothing.—Fur and feathers are of great advantage to animals living in cold climates, because there is considerable dead air space among both hair and feathers which keeps the heat of their bodies from being quickly conducted away. Have you ever seen a bird ruffle up its feathers on a cold winter's day? In this way it increases the amount of dead air space between its feathers.

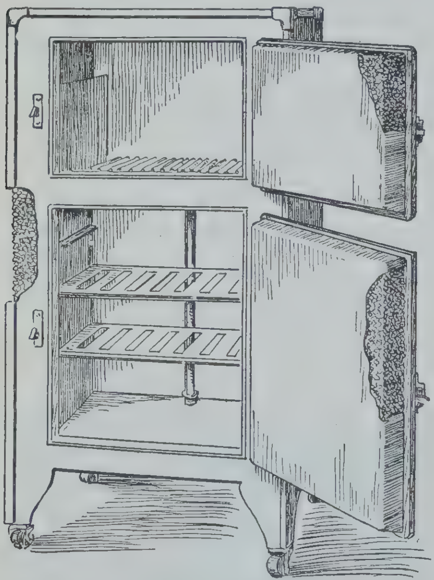


Fig. 154. The walls of this refrigerator are filled with porous cork or other non-conducting material. What is the advantage of this?

The clothing that we choose to keep us warm in the winter time is made from such materials as woollen cloth, felt, leather, and fur. Being porous, these materials contain innumerable air spaces, which make them very poor conductors of heat. When used as clothing, therefore, they prevent the loss of heat from our bodies.

The fibres of cotton, linen, silk, and rayon are much smoother than the fibre of wool. In consequence, they do not form so many dead air spaces when woven into fabric. These materials will conduct heat freely from our bodies, and therefore make excellent clothing to keep us cool in summer.

The refrigerator.—During the heat of summer, bacteria get into food and milk, develop rapidly, and frequently destroy

both the food and the milk. If food is kept cold, these bacteria cannot develop. This is the purpose of refrigerators. A refrigerator is a box, made with non-conducting walls (Fig. 154). If food is enclosed in this box, together with ice, it will keep cold for a long time, because heat cannot easily enter through the non-conducting walls.

The thermos bottle.—A thermos bottle is composed of two glass bottles, one within and a little smaller than the other. They are joined together at the neck and surrounded, for protection, by a considerably larger metal container. The air is removed from the space between the bottles, thus creating a vacuum, which is a very poor conductor of heat (Fig. 155).

When a hot liquid is put into this bottle and a cork stopper put in place, heat cannot readily escape, because both the glass and the vacuum are very poor conductors of heat. On the other hand, if an ice-cold liquid is enclosed in this bottle, it will remain very cold for a long time, because heat cannot easily enter from the outside.

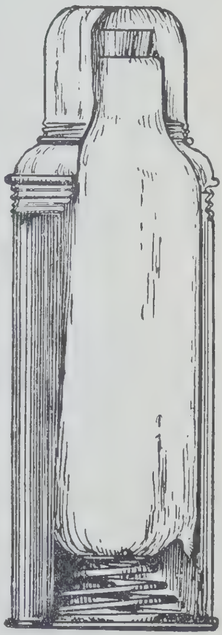


Fig. 155. A thermos bottle. Give two reasons why a thermos bottle will keep in heat. Try to find a third reason.

Question Outline

(1) List the following materials under the headings of *Good Conductors* and *Poor Conductors*: copper, brick, porcelain, iron, stone, air, water, granite, aluminium, glass, paper, lumber, felt. Suggest other materials to add to each list. (2) Name three of our best conductors of heat and three that are very poor. (3) Why are porous materials, like wool, fur, and feathers, such poor conductors of heat? Explain the advantage of this to us. (4) When you hold your hand on a woollen blanket, it feels warm; but, when you place it on a piece of iron, it feels cold. Using your knowledge of conduction, explain this statement. (5) Why do we wrap ice in blankets when we wish to prevent it from melting? (6) Why is wool "warmer" than

cotton or linen? (7) Why do down comforters make warm coverings? (8) Explain how heat travels along an iron poker.

Review Outline

(1) Describe an experiment to show that some materials are better conductors than others. (2) How is heat conducted? (3) Name metals that would make (*a*) good teakettles, (*b*) poor teakettles. (4) Is the earth's crust a good conductor of heat? Is any heat conducted into the earth's crust? Is any heat conducted out? What effect has the conductivity of the earth's crust upon temperature and climate? (5) Is water a good or a poor conductor of heat? How do you know? (6) Explain why large bodies of water help to moderate winter temperature. (7) What is a dead air space? Why is it valuable in keeping our houses warm? (8) Why are coverings of fur, feathers, flannel, and wool warm, while those made of cotton, silk, and linen are usually cooler? (9) Are the materials from which a refrigerator is made good or poor conductors of heat? Why?

III. RADIATION

How does heat from a bonfire reach you?—If you walk around a bonfire, you find that heat is coming out from it on all sides. As you sit before it, your face may become hot while your back feels cold. How is the heat getting from the fire to your face?

We know that heat is sometimes transferred by *conduction.* Is this the method by which the heat from the fire is reaching your face? When a screen, such as a magazine, is held at arm's length between the bonfire and your face, the heat is prevented from reaching your face. If you quickly remove the screen, the heat is instantly felt on your face again. This evidence furnishes two reasons for believing that heat is not being conducted to your face through the air. In the first place, air is such a poor conductor of heat that, when the screen was suddenly removed, the heat could not travel *instantly* from the position of the screen to your face. In the second place, heat is conducted in all

directions (though slowly) by air, and therefore it would pass around the screen when the screen was held in front of your face. You know that this does not happen, because the heat from the fire does not reach your face as long as the screen is in position.

If air, coming in contact with the fire and being heated, were moving towards you carrying heat, it would also carry smoke. Yet you may get no smoke in your face along with the heat. Therefore, you must conclude that the heat from the fire is not being carried to you in this way.[1] On the contrary, cool air is moving in *towards* the fire from all sides. (This helps to make your back feel cold.)

The heat that reaches your face so quickly is said to be transferred by *radiation.* A fire, a hot stove, or any warm body or object always tends to lose heat by radiation. This heat (scientists call it *radiant energy*) travels out from its source in all directions, in straight lines, just as light does, and at the rate of 186,000 miles per second. When these straight lines or rays of heat (radiant energy) strike any object that is not transparent, they are either absorbed as heat or reflected off the surface of the object again (Fig. 147).

How does heat from the sun reach us?—Heat cannot be brought to us from the sun by conduction or by movements of the air, because the air which surrounds the earth does not extend very far outward and the sun is millions of miles away. It comes to us by radiation. The sun radiates heat in all directions. Only about one two-billionth of the sun's heat strikes the earth. The heat rays from the sun pass through the air surrounding the earth without heating it to any extent. Indeed, during the hottest day in summer the air a few miles above the surface of the earth is extremely

[1]When warm or hot liquids or gases, such as air, water, or steam, move from one place to another carrying their contained heat, we say that the heat is being carried by *convection.*

cold. The sun's rays will also pass through other transparent substances such as glass with little heating effect. You may sit behind a window in a bright sun and be warmed but find that the window glass through which the heat rays are passing is quite cool. When the heat rays pass through the air and strike the earth, however, they either become absorbed as heat or are reflected back into space again.

Why does the earth cool quickly at night?—Only the part of the earth on the side next to the sun is receiving any

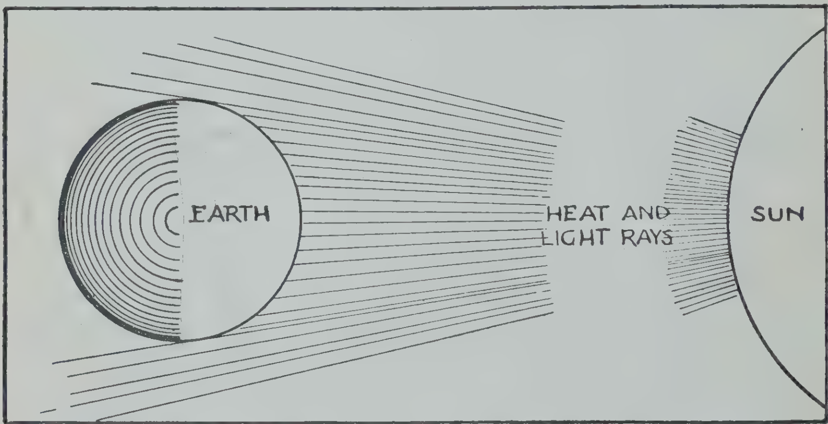


Fig. 156. Why does only one-half of the world receive heat and light from the sun at any time?

heat or light from it, because heat rays and light rays travel only in straight lines (Fig. 156). From any part of the earth lying in darkness, much of the heat received during the day and stored up in the earth becomes conducted to the surface and radiated out into space again. Thus the earth quickly cools at night by radiation.

Is heat radiated from all surfaces equally well?—The heat that radiates from any body such as the sun, the earth, or a stone must radiate from its surface. We may wonder, therefore, whether the nature of the surface of a body affects the rate at which the heat is radiated.

Experiment

Object.—To discover whether a dull, dark surface radiates heat better than a smooth, bright surface.

Apparatus.—Two tall tin cans of equal size and small in diameter, one with a blackened surface and the other with a smooth, shiny surface, two pieces of cloth or cardboard, one white and the other black, two or four thermometers, boiling water (Fig. 157).

Method.—Almost fill each can with boiling water. Cover the top of the blackened can with a black cloth or cardboard, and the top of the other can with a piece of white cloth or cardboard. Insert a thermometer in each vessel and observe the temperature of the water in each can from time to time.

NOTE.—If you have two more thermometers, mount one on a stand at a distance of about one inch from the blackened can, and arrange the other at an equal distance from the shiny can. Notice which thermometer shows the greater rise in temperature. This will also tell you from which surface radiation is more rapid.

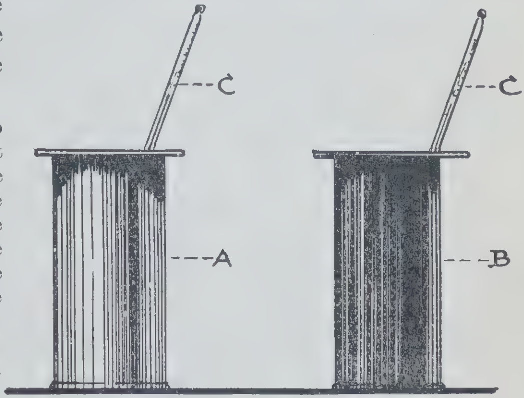


Fig. 157. A, Tall can with smooth shiny surface. B, A similar can with blackened surface. Each can is almost filled with boiling water. From which can will the heat of the water radiate more quickly?

Observation.—Which can of water cools the more rapidly?

Conclusion.—From which surface is heat radiated the more quickly?

NOTE.—A little heat will be conducted away from each can by the surrounding air. This should not affect the results of the experiment, because the rate of conduction should be the same for each can, since they are surrounded by the air of the same room.

Dark, rough surfaces will radiate heat more quickly than shiny, smooth surfaces. You will remember from a previous experiment (page 184) that dark surfaces also absorb radiant heat more quickly than shiny surfaces. This explains another effect that snow has upon temperature. Snow not only conducts heat very slowly from the earth during the winter, but it also radiates the heat very slowly. Thus

there is an advantage in having snow on the ground in winter. Being white and having smooth, shiny surfaces, snow does not radiate the heat stored up in the earth during the summer as rapidly as would the earth with its rough, dark surfaces.

Review Outline

(1) By what method does heat come to us from the sun? (2) How do we know that it does not come to us by conduction? (3) In what directions does heat radiate from warm objects? (4) At what rate does it travel by radiation? The sun is 93,000,000 miles distant. How long does it take a heat or light ray to reach us? (5) Does the earth absorb all the radiant heat that it receives? Why? (6) Why does the earth cool quickly at night? (7) How could you show that a dull surface radiates heat better than a shiny one?

Question Outline

(1) Which would *absorb* more heat from the sun, a patch of bare earth or a patch of ground of the same size covered with snow? (2) Which patch will radiate heat from the earth more quickly? (3) Why is it better to paint a house radiator a black or bronze color rather than to make it white? (4) In which will water remain hot the longer, a polished aluminium kettle or a black iron kettle? In which case would the heat be *conducted* from the hot stove to the water the more rapidly? (5) The glass of a thermos bottle is made shiny and smooth; so also is the inner side of the protecting outer cover. Explain why this is done in each case.

Sources of heat.—In a climate such as ours there is considerable variation in temperature between summer and winter. During the summer months the weather is warm. The heat received from the sun at this season is sufficient for comfort. Throughout the colder seasons of the year, however, additional heat, besides that received from the sun, is generally required to keep us warm. This is obtained chiefly by the burning of such fuels as coal and wood, and by the use of electricity.

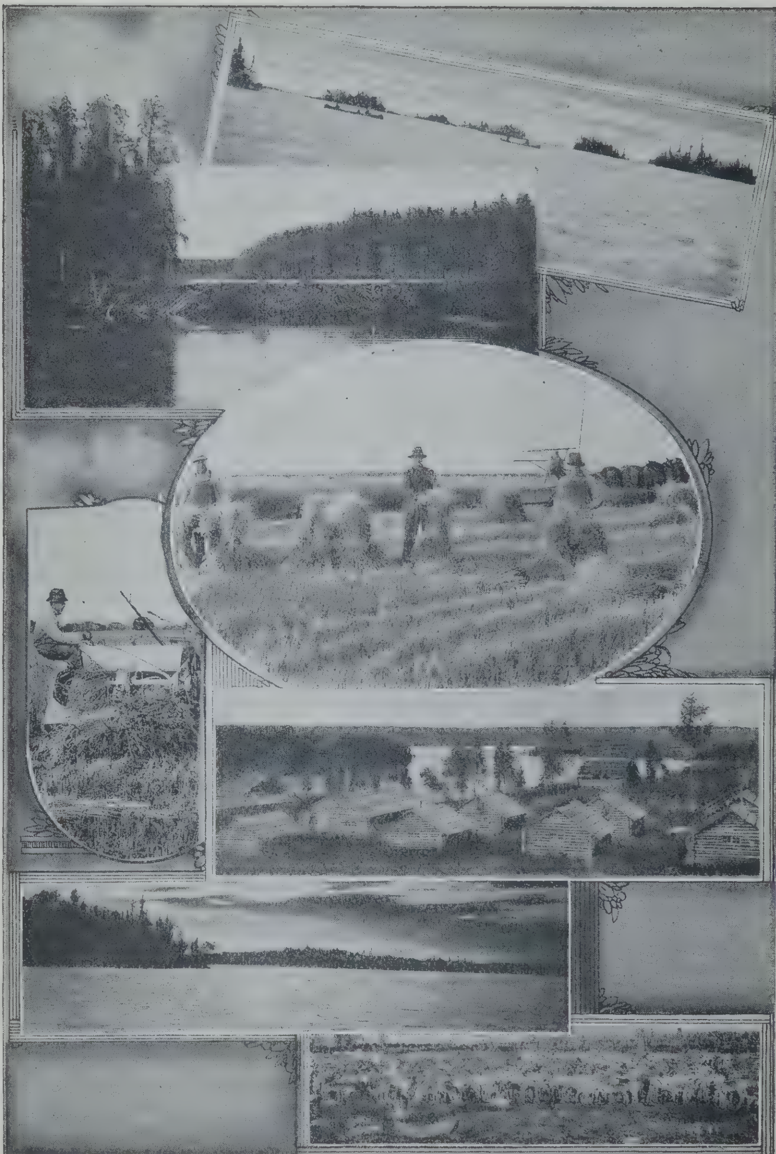
Coal is sometimes called "stored sunshine." This description might also be applied to wood, oil, and natural

gas. The energy of heat and light received from the sun by green plants promotes their growth. Much of this energy is stored up within the growing plants. When we burn one of these plants, for example the wood of a tree, in a stove or furnace, we are able to recover again much of this energy, in the form of heat. In past ages, great quantities of plant and animal material have been buried in the earth and changed into coal, oil, and natural gas. When we take these from the ground, and burn them as fuel, we regain some of the sun's energy which was stored away in the plants of long ago.

Heat energy from the sun is continually evaporating water from the earth into the air. There it condenses, forming clouds, but eventually returns to the earth as rain or snow. If it falls upon hills and slopes of land and collects into streams, it may be used to turn water wheels or water turbines as it flows from higher to lower levels. Water power developed in this way is usually converted into electricity by means of dynamos and then carried by wires to the places where it is required as a source of heat, light, and power. Here again, as in the case of coal, the source of the energy used to produce the heat is found in the energy of heat received from the sun.

Review Outline

Show that the sun is our great source of heat.



Courtesy Dept. of Agriculture, Manitoba.

Fig. 158. What change could be seen in each of these places as the temperature changes from below freezing in winter to the high temperature of summer?

PART IV

SPRING STUDIES OF PLANT AND ANIMAL LIFE

CHAPTER XXIII

SEEDS AND GERMINATION

Introduction. Seeds in the pod. — We studied in Chapters II and III how seeds are produced by the pistil of a flower (see Fig. 9 and page 10). Find in your school collection preserved specimens of pea, bean, or caragana pods, and notice that the seeds are attached by short seed stalks along one side of the pod (Fig. 159). Have any ovules failed to form seeds?

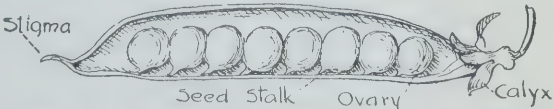


Fig. 159. The peas in a pod. Notice the short stalks by which they are attached to the pod. When they break away from these stalks, a scar is left on the seed coat. What is it called? Find the stigma, style, and ovary of the pistil that has grown to form this pod.

I. THE EXTERNAL PARTS OF A SEED

Preparation.—For seed specimens see under *Projects*, page xix. For the first lesson we shall require one dry and one soaked seed of pea and the same of bean for each member of the class. Do not let the soaked seeds spoil. If they are kept wet more than a day, they should be in 5 per cent formalin.

Examine the seeds of pea and bean, and find on each the little scar on one edge. After seeing them in the pod, can you say what was joined to the seeds where this scar now is? The scar is called the **hilum** of the seed. Hold the bean so that you are looking directly at the hilum

and find very near one end of it a tiny lump on the **seed coat** covering the seed. Hold the seed with this lump below the hilum as in Figure 160, and find at the upper end of the hilum a tiny hole. When this seed was an ovule in the ovary of the pistil, the sperm cells from the pollen grain entered through this little hole and caused the ovule to grow into a seed. This little hole is called the **micropyle,** or little gateway (*micros*, small, *pyle*, gateway). We shall see later that the little gateway has another important use. Find the seed coat, hilum, and micropyle of the pea also.

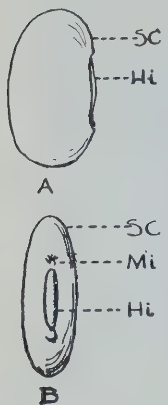


Fig. 160. This diagram will help you to find the parts. It is not exactly like your specimen, therefore do not copy it in your note-book.

Note-book Record.—You have now examined two seeds to see what they have to show you. Keeping in mind the example shown on page 11, plan your page of diagrams for the bean. Later you will require a second page for the pea and a third for the grain of corn. Keep blank pages between these for notes. Mark off a page like the sample page and make diagrams *twice natural size* in the two upper sections, "A, Side View of Bean Seed, Dry and Soaked, × 2" and "B, Edge View of Bean Seed, × 2". In B carefully label the parts that you have found, seed coat, hilum, and micropyle.


Fig. 161. Cut through the seed coat along the dotted line to see what is under the micropyle.

II. THE INTERNAL PARTS OF THE BEAN AND THE PEA

Preparation.—For this lesson, we require one soaked bean and one soaked pea.

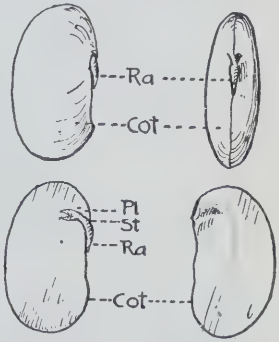
Now try to find by looking under the seed, the other use of the micropyle. Holding a soaked bean as in Figure 161, with a knife, razor blade, or needle point[1] make a cut as shown by the dotted line, then carefully raise up the flap of the seed coat

[1]Large black-headed pins are very useful for this work. They may be kept conveniently by sticking them into the edge of the text-book cover, or they may be fitted with handles by sticking them through a small cork.

and see what is under it. You will easily find the sprout that is ready to burst through the seed coat when it begins to grow. This sprout is called the **radicle** or "little root" (*radix*, root).[1] When the radicle grows, will its tip come near the micropyle? Will this be a point at which the radicle may easily break through the seed coat? What is the second use of the micropyle?

Next remove the whole of the seed coat and see the two thick starchy halves of the bean, the "seed leaves," or **cotyledons.** (*Kotyle* means hollow. Notice the hollow between the cotyledons.) The cotyledons are joined together by the sprout (Fig. 162).

On your page of diagrams of the bean, show, in the third space, a diagram of "Bean, with Seed Coat Removed, × 2".



Figs. 162 and 163. This is not the bean which you have been examining. Draw from your specimen. The upper diagram shows the seed coat removed, and the lower shows one cotyledon removed to uncover the parts between.

Now very carefully separate the cotyledons so that the sprout or radicle remains attached to one of them. This permits you to find what is at the inner end of the sprout. Two little leaves may be seen without difficulty, lying folded tightly in the hollow between the cotyledons. These two leaves and the tiny stem-tip that lies between them form the **plumule** (*plumula*, little feather) (Fig. 163).

We have now seen the whole of the young plant in the seed. It consists of a very short *stem* (st), with four leaves and a root attached to it. The two *plumule leaves* and the two *seed leaves*, or cotyledons, are on the sides of the stem, and the root or *radicle* is at the lower end. The cotyledons are large and thickened with stored food for the use of the young plant.

[1]Since only a few root cells have yet formed at the tip of this sprout, the term *radicle* has been abandoned in technical books, but its usefulness for this grade is obvious.

Lay out the two cotyledons as shown in Figure 163. Draw their outlines in the fourth space of your page far enough apart so that the labels may be printed between them without abbreviation. The title of this diagram may be "Bean Seed with Cotyledons Separated, × 2".

Having completed your diagrams of the bean, mark off the page reserved for the pea and make a similar set of diagrams, with similar labelling. On the blank pages reserved for notes write a short account of the parts that you have found, naming each part and mentioning its uses.

III. COMPARISON OF A GRAIN OF CORN WITH BEAN AND PEA SEEDS

Preparation.—For this study, two large soaked grains of corn are required for each member of the class.

External parts of the grain of corn.—Examine a grain of corn. The "grain" is not a seed out of a seed pod, but is a whole seed vessel, a dry fruit, containing one large seed.

Fig. 164. Grain of corn showing shield-shaped "germ" on one side.

The thin seed vessel clings to the surface of the seed and forms the "bran" of the grain. Can you peel off part of the bran from a soaked grain of corn or wheat?

We cannot find on the grain of corn the external parts which we found on the pea and bean because it is not a seed but is a seed vessel with a seed in it. One of the flat sides of the grain has on it a lighter-colored shield-shaped area, the broad end of the shield being near the point of the grain (Fig. 164). This shield is called the *germ* of the grain because the young plant is in it (*germen*, a bud). Find the germ.

Note-book Record.—Mark off the page set aside for the corn diagrams. Only two spaces are required. In the first, draw a diagram of "Side View of Grain of Corn, showing Germ, × 2".

While drawing, notice the ridge along the middle of the shield. What is under it? After you have drawn the diagram, peel off the bran from the germ and see if you can

find the young plant. Its root tip, or radicle, is ready to burst out through the bran near the point of the grain, and its plumule is ready to push through near the top of the shield.

Internal parts of the grain of corn.—The whole of the young plant may be seen more readily by cutting through the grain lengthwise. This makes two new flat surfaces that we can examine; each of them is called a "longitudinal section" of the grain.

Lay out the second soaked grain with the germ side upward and obtain a longitudinal section by cutting it in two with a very thin, sharp blade (Fig. 165). Place the edge of the blade along the middle of the ridge as indicated in Figure 164, and make a sliding cut.[1]

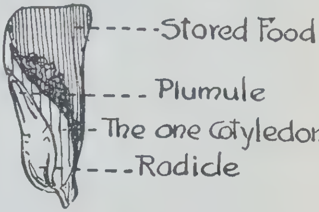


Fig. 165. Longitudinal section of grain of corn. How many cotyledons has it? Find the plumule and radicle in your specimen.

Holding the longitudinal section of the grain in the position of Figure 165, notice that the whole of the inside of the grain is in two divisions, the germ in the lower part near the point, and the large store of food in the upper part. Much of this food is corn starch and may be white in your specimen. In the germ, find again the radicle, pointing downward, and the plumule, pointing upward. Along the surface of the germ next to the stored food is the *one* cotyledon. In corn and other grains there is only one cotyledon, instead of two as we found in the bean. You can readily see also from the specimen that the supply of food for the young plant is *stored outside the cotyledon,* not within it as we found in the bean.

We have found two great differences between the seed inside the grain of corn and the seeds of the pea and bean. What are these differences?

[1]Safety razor blades are excellent for this work. Double-edged blades should be placed in handles or broken in two lengthwise with a pair of pliers to make them less likely to cut fingers.

Plants whose seeds have only one cotyledon are called **monocotyledons** (*mono*, one), and plants whose seeds have two cotyledons, or seed leaves, are **dicotyledons** (*di*, two). These are the two great classes of flowering plants. The grasses and grains, lilies, rushes, and similar plants belong to the monocotyledon class, while most of our common trees, shrubs, and other flowering plants are dicotyledons.

Note-book Record.—Now draw a diagram of the longitudinal section calling it "Longitudinal Section Through a Grain of Corn, × 2". In this diagram mark the "Bran", "Stored Food" (mostly corn starch), "The One Cotyledon", the "Plumule", and the "Radicle".

IV. GERMINATION. THE AWAKENING AND GROWTH OF THE YOUNG PLANT IN THE SEED

We have found the young plant that is asleep in the seed of pea and bean and in the grain of corn. We have seen also the store of food that is provided for it when it wakens. We shall now germinate some seeds and watch the young plants grow until they have roots and leaves that enable them to make food for themselves. Each member of the class should set up a complete experiment and make a record of it.

Preparation.—In order to see the sprouting and growth of the seeds we must have them in a clear glass vessel, such as a tumbler. The outside of the glass should be provided with a cover to keep out the light when we are not observing the seeds (see Appendix, Sec. 8). This allows the roots to grow without light as they do in the ground. Soaked seeds of pea, bean, corn, sunflower, and one other small seed or grain are required, two of each for each tumbler.[1]

1. Preparing the seed bed.—In the first lesson, prepare the tumbler, its cover, and the bulb fibre, moss, or sawdust and blotting paper in which the seeds are to be planted

[1] These seeds are to be planted during the second lesson. They should be placed in water twelve to twenty-four hours before they are needed.

(see Fig. 166 and Appendix, Sec. 8, First Lesson). When you have the seed bed ready, write an account of what has been done, illustrated by a diagram of your experiment.

2. Planting the seeds.—In the second lesson, plant the seeds in tumblers as directed in the Appendix (Sec. 8, Second Lesson) and set them away for three or four days in a warm place. In your note-book write an account of how this was done.

3. What wakes up the young plant? — The young plant in each seed is alive. It may sleep for a long time (in some cases for many years), or it may waken in a short time and grow to a large plant. Let us try to find what it is that wakes up the young plant and makes it grow. To do this, set up three additional tumblers for the class to observe, with seeds in them like those which you have already planted, but from each of these tumblers omit one thing.

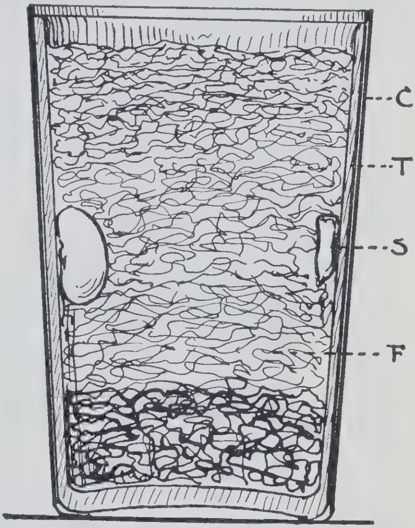


Fig. 166. Seeds planted in clear glass tumbler. C, Cover to exclude light from roots. T, Tumbler. S, Seeds planted with sprouting side against the glass. F, Bulb fibre, coarser parts in bottom for drainage.

In A, leave out the water; plant the seeds in dry fibre.

In B, leave out, or rather keep out, the air by filling the tumbler to the top with water and keeping it full.

In C, leave out the heat by keeping the tumbler in a cold place.[1]

[1]If no cold place is available, wrap the tumbler in wet cheesecloth and set it in a shallow dish of water, placing it in an open window or before a ventilator, where there will be a draught of air that will evaporate water from the cloth. Will this cool the seeds? Place a thermometer in the fibre to see how cool it is kept.

Watch these three tumblers and compare the growth of their seeds with the growth of the seeds in the other tumblers that have water, air, and heat. Is water necessary for waking the young plant? Is air necessary? Is heat necessary? Why does a crop not grow if the field is flooded?

Additional Experiment in Germination

Object.—To find whether seeds can germinate in *any* kind of air, or whether they must have *fresh* air such as people and animals require for breathing.

Method.—Select two test-tubes equal in size. In each insert along one side a strip of blotting paper half an inch wide, and in the bottom a plug of cotton batting. The blotting paper should project two inches beyond the mouth of each tube. Fill the tubes with water to soak the blotter and the cotton, then pour out the water. Now arrange a row of soaked peas along the strip of blotting paper in each tube. Two rows may be put in if the test-tubes are wide. Put a close-fitting cork or rubber stopper in one tube. This will prevent fresh air from entering this tube. To prevent the peas from rolling out of the other tube, place at the end of the row of peas a piece of rubber, a flat pebble, or any other obstruction smaller than a pea. This will allow the heavy carbon dioxide gas produced by the seeds to flow out of the tube, and fresh air will enter and take its place. Slip an elastic band around the two tubes and support them in a sloping position as shown in Figure 167, with the blotting paper dipping into water. Put the tubes in a warm place, preferably in the dark.

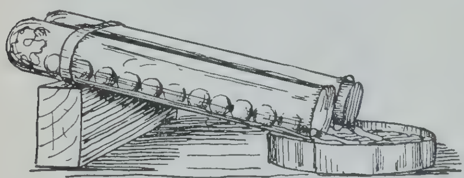


Fig. 167. Experiment to find whether seeds require *fresh* air for germination. One tube is open. The other is tightly corked.

Observation.—How many seeds have germinated in each tube at the end of three days? six days?

Conclusion.—Do seeds require *fresh air* for germination?

4. Testing seeds and disinfecting them before sowing in field or garden.—Many farmers and gardeners test their seeds or grains before sowing them in the spring. If a farmer finds that only three-quarters of his seeds will grow,

what should he do about it? You can readily see that he must sow extra seeds to allow for those that do not grow.

The experiments in which you have planted seeds in tumblers are tests of the beans, peas, and other seeds that you sowed. If they all grow, a gardener would be safe in sowing seeds from the same packages. Farmers and gardeners, however, test a larger number of seeds than could be sown in a tumbler, usually one hundred seeds, and find what percentage grow. From this they know how many will be wasted, and how many to sow. A box of soil in the house is a good tester, but a germinator is better because it enables us to see what is wrong with seeds that do not grow. Set up a "rag doll germinator" as described in the Appendix (Sec. 9) or one of the smaller kinds of germinator shown in Figure 168, and test seeds or grains that are to be sown in the garden or fields at home. Make a record of your test and of the percentage that grow well.

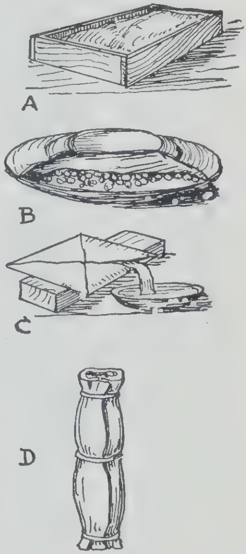


Fig. 168. Four kinds of simple germinators. A, Box of soil. B, Dinner plates with sand, cloth, or blotting paper between. C, Folded blotter wrapped in waxed paper, wick in one corner. D, Rag doll germinator.

In making this test you may find that some of the seeds become mouldy soon after you place them in the germinator. These are the weaker seeds, and they probably had spores (like seeds) of mould upon them when planted.

Many wheat grains have spores of smut disease upon them; we say that these grains are "infected with smut." The smut is a plant somewhat like mould. If the smut spores are allowed to remain on the seed wheat, they grow on the wheat plants. The plants are then diseased and do not

produce grain (Fig. 169). Every year the grain crops of Canada are damaged to the extent of several millions of dollars by smut alone. For this reason farmers should always disinfect their wheat before sowing it. This is done by moistening the grains with formalin solution[1] to kill the smut spores. Some kinds of smut can be destroyed in this way, others cannot.

Fig. 169. Heads of wheat. A, Healthy head of Marquis wheat. B, Wheat infected with covered smut. This smut is prevented by disinfecting the seed with formalin. C, Wheat infected with loose smut. This is not prevented by formalin or other chemicals.

Do not disinfect seeds before testing their germination unless they would be disinfected before sowing in the field or garden.

5. Observing seeds that have sprouted.—Instead of digging up our seeds to examine them as they sprout in the tumblers, we shall examine seeds that have sprouted in a germinator.[2]

Preparation. — For this lesson each member of the class requires a seed of pea and of bean and a grain of corn having sprouts an inch or more in length, with branches showing.

We have seen soaked seeds and have taken off their seed coats to see what was under the micropyle. Now look at the sprouted pea and bean seeds and see if in each the sprout broke through the seed coat near the micropyle.

[1]One pound of formalin to 40 gallons of water for 40 bushels of wheat. Two ounces of dry copper carbonate powder per bushel may be used instead of formalin for wheat. See Circular No. 85, *Cereal Smuts*, Publications Branch, Department of Agriculture, Winnipeg.

[2]These were started previously and will be ready for this lesson.

In the grain of corn the roots may break through the bran in several places near the top and bottom of the germ, but the first root usually appears near the point of the grain.

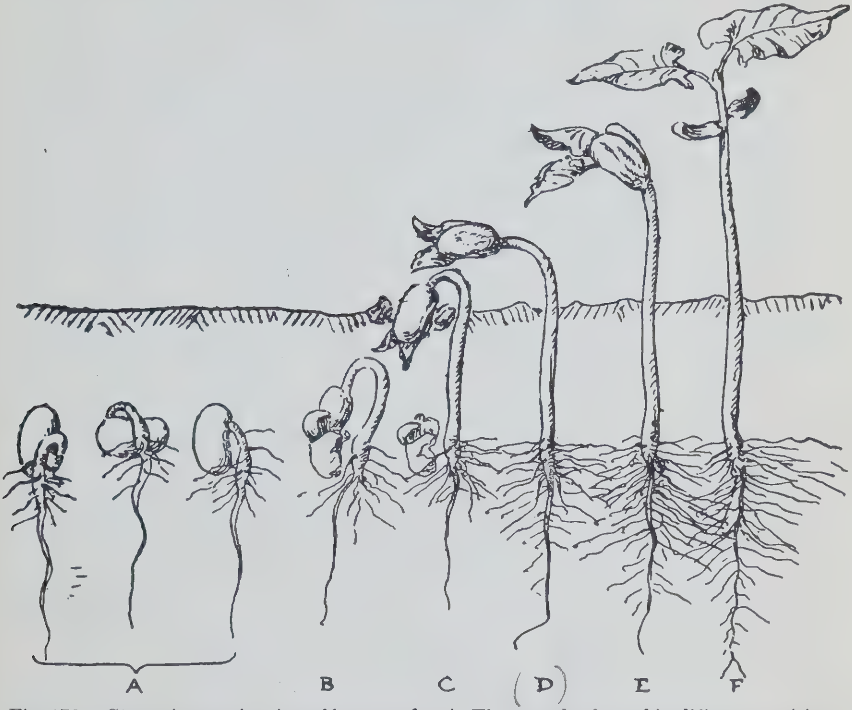


Fig. 170. Stages in germination of bean seed. A, Three seeds planted in different positions sending out their first root. What direction does it always take? B, The stem is lengthenening and drawing the cotyledons out of the seed coat. Notice that the cotyledons are being pulled, not pushed, upward through the soil. C, D, The bend of the stem has pushed through the surface of the soil. The old seed coat is held by the soil where it was planted. The root is growing larger at each stage. D, E, The bend is straightening up. The cotyledons are separating and the plumule leaves spreading out to the sunlight. F, The cotyledons are withered and shrunken, their stored food being all gone. The plumule leavesare now full-grown and are able to make new food for the whole plant. Germinationis complete. Notice the tiny stem tip between the plumule leaves, ready to lengthen the stem.

Remove the seed coats of the sprouted pea and the bean and find what part in each enlarged to form the first sprout or root. Then carefully remove one of the cotyledons of each seed and see whether the plumule has yet begun to grow. Why is it important that the root should begin to grow first?

Note-book Record.—Plan a page of diagrams with the title, "Germination of Bean Seeds". On this we shall draw four diagrams of different stages in the germination of this seed. In the first space, show "Sprouted Bean with One Cotyledon Removed, × 2". Label on it "Plumule", "Cotyledon", and "Radicle Grown to a Root".

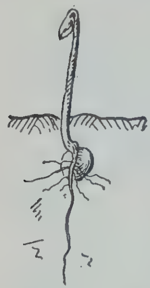


Fig. 171. Pea seedling. Notice that the plumule is going up, but the cotyledons are *not*.

6. Observations upon seedling plants.—Now we may return to the seeds that we planted in the tumblers and see how they grow after they have sent out the first sprouts. Do the first sprouts grow in the same direction in seeds that you planted in different positions? In what direction do they grow?

(*a*) *The bean.*—Watch the bean seeds from day to day, and see the stages through which they pass. Look for all the steps shown in Figure 170.

(*b*) *The pea.*—While you are watching for the stages in the germination of the bean, notice the differences between each stage of the bean and the corresponding stage of the pea. Does the stem lengthen and raise the cotyledons above the soil in the pea (Fig. 171)? What is the first part to appear above ground?

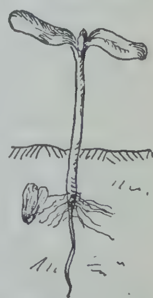


Fig. 172. Sunflower seedling. The cotyledons have come above ground and have flattened out, forming thin green leaves.

(*c*) *The sunflower.*—Notice three points particularly about the germination of the sunflower seed: (1) Does it come through the surface of the soil with an arch bend of the stem like the bean, or without the bend, as in the pea? (2) Watch the cotyledons of the sunflower carefully. Do they ever become green leaves (Fig. 172)? Do they fall off when the food stored in them is used up? (3) Is the plumule large or small when it first appears?

(*d*) *The corn.*—The one cotyledon of the corn (Fig. 165) has no food stored in it, but, when the young plant wakes up and begins to grow, the cotyledon absorbs

the starch stored beside it in the upper part of the grain. Does the main body of the grain come up out of the ground as the seed of the bean does? Watch the plumule pushing through the surface of the ground, protected by a special "plumule sheath" that prevents it from being injured by the soil. Then watch for the green plumule pushing through the top of the sheath, as shown in Figure 173.

Fig. 173. Corn seedling. Notice the plumule going upward. It has pushed through the end of its protecting sheath.

Note-book Record.—On the page which you began for bean diagrams, make three more drawings showing various stages in the germination of the bean. On another page with the title, "Germination of Seeds and Grains," draw one diagram each of pea, sunflower, corn, and one of your other plants. In each case show all that you can see of the young plant in your tumbler experiment. Label the plumule, the cotyledons, the root, and any other parts that can be seen.

When you have made the diagrams, write a short account of the germination of each seed, pointing out how the growth of each seedling differs from the growth of the bean seedling as to method of pushing through the soil.

7. What the seedlings require to enable them to continue their growth.—When your plants growing in fibre in the tumblers have grown to a height of six or eight inches, they will begin to show signs of dying off. Can you suggest a reason? Have they used up their stored food? Have they been able to obtain the mineral salts that they would have found in soil? To find whether this is what they need, procure some of the plant food tablets sold by dealers,[1] and place one tablet (powdered) in *alternate tumblers* throughout the class. Another method is to remove as much fibre as possible without disturbing the roots and replace it with good garden soil. Observe whether those plants that have been fed survive better than those that have not. Some plants will produce seed if given a tablet of food about once a month. What must plants have in order to continue growth beyond

[1]"Fertabs" or "Sterlingworth" tablets are satisfactory.

the completion of germination? When you have completed your observations and note-book records of germination, the fibre with the young plants growing in it may be slipped out of the tumbler and planted in the garden. One or two of the plants may grow all summer.[1]

Question Outline

(1) What is the little scar on the edge of a bean or other seed? (2) What two uses has the little hole at one end of the scar? (3) What parts may be seen when the seed coat of a pea or bean is removed? (4) What is to be found between the cotyledons? (5) What part in the seed grows out to form the first sprout? (6) Why are the cotyledons of pea and bean so large? (7) How many cotyledons has the bean? the pea? the grain of corn? (8) What is the chief difference between the seeds known as "monocotyledons" and those known as "dicotyledons"? (9) Look at the longitudinal section of the grain of wheat (Fig. 174). Is it a monocotyledon or a dicotyledon? (10) How does the cotyledon of the grain of corn differ from the cotyledons of the pea and the bean? (11) Where is the store of food for the young plant in the corn? (12) Is the bran of the grain of corn a seed coat or the seed vessel? (13) What three things did you find are necessary to wake up the young plant in the seed and start it growing? Does the seed require light? Will it germinate without soil? (14) How do farmers and gardeners test the seed that they intend to grow? (15) Of what use is it to test seeds before sowing them? (16) How does a farmer protect his grain crops against smut disease? (17) In the sprouted seeds what part has grown to form the new root? (18) What grows up to form the stem and the leaves? (19) Which of the young plants that you have grown raise their cotyledons above the ground? (20) In which do the cotyledons become flat green leaves? (21) What becomes of the cotyledons of the bean? (22) The cotyledon of the corn has no food in it, and it does not come up to form a green leaf. How is it useful to the young plant? (23) Why cannot seedling plants grow to full size and produce flowers and seeds when they are growing in fibre or sawdust?

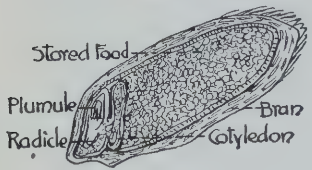


Fig. 174. Longitudinal section of grain of wheat. Look for the same parts that you found in the grain of corn.

[1]The fibre cannot be used another year unless sterilized by boiling half an hour in water, or baking in an oven or otherwise.

CHAPTER XXIV

INCREASE OF INSECTS IN THE SPRING

Introduction. — In Chapter XI we studied the cabbage butterfly and other harmful insects. We shall now study the life history of one or more of the insects that come to us with the spring, and see how each insect that survives the winter may during the summer increase to many. From these observations we may be able to discover methods of checking harmful insects.

I. THE MOSQUITO

Preparation.—Like the other insects that you have studied, the mosquito develops from an egg. The eggs of the mosquito are difficult to find because they are very small and are often attached to plants and other objects on the bottoms of ponds. When the ponds dry up, the eggs remain alive until water comes again. We can, however, easily obtain larvae, or "wrigglers" as they are called on account of the way in which they move through the water (see Appendix, Sec. 2). These hatch out of mosquito eggs when water collects in ponds, stagnant pools, ditches, and other places in the spring (Fig. 175).

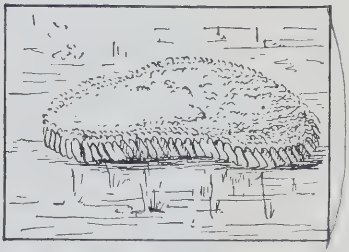


Fig. 175. This is the egg raft of one kind of mosquito, greatly magnified. It actually appears like a speck of soot floating on the water. The eggs of other kinds of mosquitoes are laid separately and sink.

For this lesson we shall require one or more sealers or small pails of pond water containing enough wrigglers to supply each member of the class with several specimens. Along with the water there should be blades of grass, or weeds from the bottom of the pond. These will be covered with a slimy substance which serves as food for these tiny animals. The water should not be left standing in the hot sun.

Each member of the class should fill a clear glass tumbler at least half full of pond water,[1] containing, if possible, several wrigglers. Add a few blades of the grass from the pond. Cover each tumbler with a piece of wire netting or cheesecloth cut round and bent down tightly over the edge. This will prevent the escape of mosquitoes after they emerge from the water.

The life history of the mosquito. — Look closely at the wrigglers in your tumbler. If you have a magnifying glass, you will be able to see them more clearly. Are they all the same in shape, or are there some with their heads hanging downward and others with their heads upward? The former are larvae, and the latter are pupae (Fig. 176).

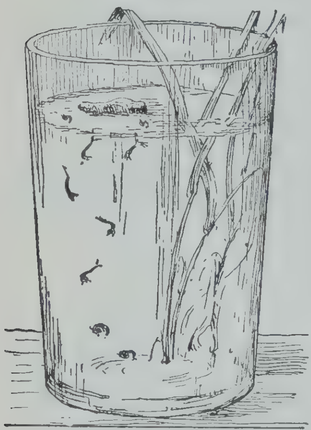


Fig. 176. Why are blades of grass or sticks from the pond put in the tumbler? What two stages in the life history are shown?

The larva.—Place the tumbler on the desk and leave it motionless until the wrigglers begin to swim naturally. Do they hang straight downward from the surface of the water or at an angle? Can you see the little tube that each larva pushes up through the surface to obtain air? Does this tube come from the end of the abdomen or from one side (Fig. 177)? Can you explain why the larva hangs at an angle? Can you see the three main divisions of the body — head, thorax, and abdomen? Does the abdomen seem to be made up of segments? Notice the two projections on the end of the abdomen. One is the tube through which the wriggler breathes. The air that passes down through this tube is carried to all parts of the body needing it. The wriggler closes the *breathing tube* when it goes down into the water.

[1]If it is difficult to carry sufficient pond water to the classroom, obtain enough to fill the tumblers to a depth of an inch; then add other soft water.

Can you see any bristles of hair projecting along the surface of the head, thorax, and abdomen? Look closely at the hairs about the mouth to see if they are moving. By these bristles on the head the insect sets up currents in the water that move food towards its mouth. The food consists mostly of tiny particles of plant and animal material in the stagnant water. The particles are so small that you cannot see them.

What is the name of the feelers found on the head of a cabbage butterfly? Do you see a pair of them on this larva?

Now disturb the tumbler. How do the wrigglers seem to move themselves along? When they stop wriggling, do they float or sink? Do they have to work to come up for air or to go down for food?

Examine the other projection on the end of the abdomen. Can you see the gill flaps on it? Do you think that this part of the body aids in swimming?

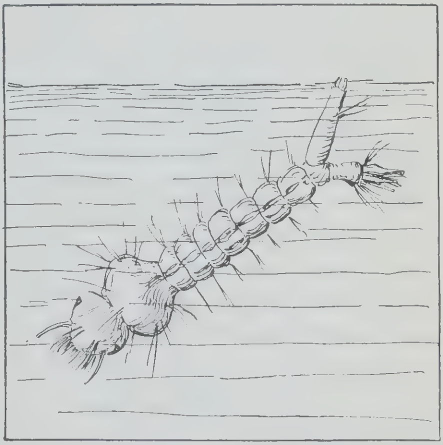


Fig. 177. Larva of mosquito ($\times 10$). How does it hang from the surface? What is it doing?

In about a week a mosquito larva, if it is well fed, is fully developed. During this period it moults several times. Each time it moults it casts off its tough outside cover, and the new covering, which was formed under it, stretches to a larger size before becoming tough. The cast-off clothing which fitted the larvae between moults may be seen in water where numerous mosquitoes are developing.

The pupa.—After the larva has moulted several times and become fully developed, it enters the pupa stage. How can you distinguish a pupa from a larva? Find a pupa in your

tumbler. Where does it rest much of the time? Does it need to work to get up to the surface or to go down for food? Compare the size of its head and its thorax with those of a larva. Do you see two horn-like projections from the thorax? Are they pushed up to the surface of the water? Through these two tubes the pupa breathes (Fig. 178).

Is the abdomen segmented? Do you find two projections on the end of the abdomen, as in the larva, or has a change taken place? Look for the "tail fin" at the end of the abdomen.

Fig. 178. Pupa of mosquito (×10). How does it differ from the larva? Where are its breathing tubes? Does it sink or float when not working?

Can the pupa float to the surface? Does it seem strange to you that the pupa moves at all? Recall whether the pupa or chrysalis of the cabbage butterfly and of other insects that you have studied moved about.

Cover your tumbler with netting, leaving in it one larva or wriggler. Place the tumbler in a shady position where it can be observed for a few days. Notice when the larva changes to a pupa and make a careful record of the date so that you may find out how many days it takes the pupa to develop into an adult mosquito.

The larva has no legs or wings. During the pupa stage these develop inside the skin. When fully developed, the pupa comes to the surface and moults. The tough outer skin splits along its back. The mosquito works itself out of this floating cover, which serves as a raft on which it may stand until its wings are dry. Then, if a ripple or a gust of wind does not upset the tiny craft and drown the mosquito, it will fly away.

The adult.—While the mosquito which has emerged from your pupa specimen is clinging to the cover or side

of the tumbler, carefully pour out the water through the screen cover so that you may not drown the mosquito while examining it.

How many legs has your mosquito? How many wings? How many main divisions are there of the body? What are they called? To what part are the legs and the wings attached (Fig. 179)?

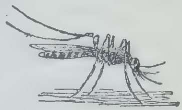


Fig. 179. Adult mosquito (×2). How is it like and unlike other insects that you have observed?

Examine the head. Has it any antennae? Compare your mosquito with others in the room and observe that they are not all alike. The antennae of the male are more feathery than those of the female. Which have you? The antennae are the hearing organs of this insect as of the honey-bee. Can you see the mosquito's mouth? Have you seen the needle-like mouth parts on a mosquito that was trying to get blood from you? The needle is in reality a very fine tube through which blood, or sap from plants, is sucked up. Mosquitoes feed also upon the nectar of flowers. Most of them do not find an opportunity to feed upon blood but live on plants only.

Note-book Record.—Write an account of the mosquito which you have observed telling: (1) where the larvae were found, (2) how they develop, (3) how the larvae and pupae breathe, (4) how they swim, (5) where they rest.

How we may destroy mosquitoes before they leave the water.—Recall how both the larva and the pupa breathe. If it were possible to prevent them from getting air at the surface of the water, could they remain alive? In a tumbler half full of water put some larvae and pupae of mosquitoes. Pour in enough crude oil or lubricating oil to cover the surface of the water. Do the larvae and pupae succeed in developing into mosquitoes when there is oil on the surface of the water? They may not die in a few minutes, as you would if your air supply were cut off, because they are able

to obtain a little air that is dissolved in the water. Eventually they die from suffocation and other effects of the oil.

By spraying oil on ponds, in ditches, and in all other places where stagnant water is found, the development of mosquitoes in any district may be checked. For this purpose it is best to use crude oil or old engine oil to which has been added a little carbolic acid. Unfortunately this oil will also destroy fish and other animals that live in the water and help to destroy mosquitoes, larvae, and pupae. A pond or larger body of water that is clear and deep should therefore not be sprayed with oil. It is better to stock it with fish. They keep it comparatively free of larvae. As fish remain in the water from year to year, further treatment is unnecessary, whereas oil must be applied frequently.

Probably the most thorough method of ridding a district of mosquitoes is to drain all areas in which mosquitoes may breed. Before construction of the Panama Canal could proceed, great areas of swamp had to be drained in order to get rid of mosquitoes. In this case they were spreading two deadly diseases known as malaria and yellow fever. The number of mosquitoes about your own home may be decreased by draining away, spraying, or stocking with fish all stagnant water in which they may develop.

How mosquitoes may multiply.—There are many different kinds of mosquitoes. Some kinds lay from one hundred to two hundred eggs, while others lay from two hundred to four hundred eggs. Let us suppose that one mosquito lays one hundred and fifty eggs. About half of these will hatch out to female mosquitoes that may lay more eggs. If each of the seventy-five females lays about one hundred and fifty eggs, more than ten thousand mosquitoes will probably hatch.[1]

[1]Some species of mosquitoes hatch in the same season as the eggs are laid. These may develop to adults and lay eggs again before the autumn. The eggs of other species do not hatch until the following spring. See Report No. 17 of the National Research Council, obtainable from the King's Printer, Ottawa.

Calculate how many mosquitoes may develop under favorable conditions from eggs laid by these ten thousand mosquitoes. It will readily be seen that thousands and thousands of mosquitoes may come from the eggs laid by one mosquito. Fortunately not all of the mosquitoes hatched live long enough to lay eggs, but in any district where there are favorable conditions they increase rapidly. This, you will remember, is true also of weeds. They produce great numbers of seeds, and, though they do not all grow to plants, they increase rapidly in any place where they are not kept down.

Question Outline

(1) How can you tell the difference between larvae and pupae of mosquitoes in water? (2) How many divisions are there in the body of a larva? (3) What are the uses of the two projections at the end of the abdomen? (4) What is the food of the larva? How does it bring the food into its mouth? (5) Did you find any of the cast-off clothing (outer covering) of the larva? (6) How does the pupa breathe? (7) What are the differences in appearance between a pupa and a larva? (8) In what three ways may the larvae and pupae in ponds and ditches be destroyed? (9) Describe the adult telling: (*a*) parts of its body, (*b*) parts attached to each division, (*c*) the difference between the antennae of the male and those of the female, (*d*) its food, (*e*) when it lays its eggs. (10) Account for the rapid development of mosquitoes where there is an abundance of stagnant water and the weather is warm.

II. THE POTATO BEETLE

Introduction.—An insect which frequently devours the leaves of potatoes in Canadian gardens is the potato beetle (Fig. 53, page 47). This insect has a complete metamorphosis, passing through the same stages as the cabbage butterfly, the horse-fly, and the mosquito, namely, egg, larva, pupa, and adult. These stages are shown in Figure 180.

Preparation.—Find specimens in the larva and adult stages. Put them on a potato plant and leave them there until they are required.

If possible, find some bright orange-yellow eggs on the under side of potato leaves and place them in the cage with the potato plant.[1] When hatched, the larvae will feed on the plant. Preserve in 5 per cent formalin at least one adult for each member of the class. For class study each member should have specimens of egg, larva, and adult. Keep them on a few potato leaves in an insect cage. The leaves will keep fresh for days if they are left on a short piece of potato stem in a jar of wet earth in the cage. Do not use an open jar of water. If you find a potato plant partially destroyed by these insects, bring it to the classroom.

The eggs.—Are the eggs laid singly or in clusters? What is their color? On which side of the leaf did you find them? What is the advantage of this position? How many were there? In about a week, if the weather is favorable, tiny larvae will hatch from the eggs. We know that they are not bugs because they have biting jaws, and true bugs have sharp beaks for piercing and sucking. Beetles have biting jaws.

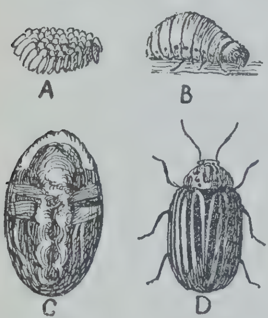


Fig. 180. The four stages in the life history of the potato beetle. A, Egg cluster. B, Soft-bodied larva. In this stage it eats ravenously like the caterpillar of the butterfly. C, Pupa buried in the ground. D, Adult. What forms the hard covering on its back?

The larva. — Examine one of the larvae and find on it the *head*, the *thorax*, and the *abdomen*. Each of the three sections of the thorax has a pair of legs attached to it. Is the abdomen made up of segments? What is its color? Are there any marks on it? The color would attract the attention of birds, but the taste is so disagreeable to most birds that they do not eat it. (See *Warning coloration*, page 96.) Is the body soft or hard? What is its shape? Has it any wings? Has it antennae? Watch it feeding. Does it bite pieces out of the leaf or suck the sap?

[1] A good method is almost to cover a potato with soil in a large insect cage similar to the one shown in Figure 70. Keep the soil moist. This must be done a month before it is required. It will then be ready when eggs and larvae or adults are found. Some of the larvae may bury themselves in the soil and enter the pupa stage.

The larva feeds and grows rapidly. In a short time it may do much damage to the leaves of the potato plant. In about three or four weeks it grows to full size and stops eating. Does it moult during this time? When it is full-grown, it goes down into the ground and moults, becoming a pupa.

The pupa.—Unlike the pupae of mosquitoes, the pupae of potato beetles are inactive. Underground they develop into adults in about two weeks. Then they come out of the ground, and the females lay eggs. During the summer the eggs hatch, and by autumn full development has taken place. The adults of this second generation, however, do not come out of the ground until the following spring.

The adult.—Now examine one of your adult specimens. Can you see the three divisions of the body? How many pairs of legs are attached to the thorax? Lift up the outer hard wings of a preserved specimen and find the delicate flying wings. How many dark lines are there along each wing cover? Is the abdomen divided into segments as in the case of the larva? Is it covered with a hard outer covering as in the case of the grasshopper? When a potato plant is disturbed, the beetles sometimes drop to the ground and seek safety in the earth. Would the hard wings and body covering help to protect the insect if you stepped on the ground beneath which it is buried?

Examine the head. What is its color? Can you see the pair of compound eyes? Has it a biting mouth like the larva? To answer these questions notice how it feeds.

How to destroy potato beetles.—It requires very little observation to see how the larvae and the adults of potato beetles harm potato plants. They have biting jaws with which they rapidly eat away the blades of the leaves, usually from the edges. The best method of destroying these insects, therefore, is to spray food poisons on the leaves (see page 86).

Where conditions are unfavorable, many of the pupae do not survive the winter. Some of those that do survive are destroyed by birds such as the rose-breasted grosbeak and the flicker, and by other animals. Even in our climate a number of adult potato beetles and pupae are able to live over winter buried in the ground. When they come out of the ground in the spring, they multiply quickly. Each female may lay five hundred or more eggs, which she places in clusters of twenty-five to fifty on the under side of leaves. These hatch into larvae in a week of warm weather and grow to full size in about three weeks, during which time they moult four times. They then dig down into the earth and, after spending one or two weeks in the pupa stage, emerge as adults. Thus, from a single female potato beetle that survives the winter, nearly five hundred new adults may develop within six or eight weeks. If two hundred and fifty of these are females and none of them is destroyed by birds or other animals, they may in another month produce more than one hundred thousand new adult beetles. Think of the many potato leaves that would be required to feed all these larvae up to the full-grown stage! Think of the many potatoes that could be destroyed by the "children" and "grandchildren" of one female potato beetle! If one hundred beetles destroy one plant, and twenty plants produce a bushel of potatoes, the descendants of one female beetle that survives the winter could destroy fifty bushels of potatoes. If, however, the descendants of each wintered-over female destroyed only one bushel instead of fifty bushels, it would still be worth our while to destroy the adults that come out of the ground in the spring.

Question Outline

(1) Where are the eggs of the potato beetle found? How would you recognize them? (2) Compare the larva and the adult as to: (*a*) marks on

the body, (*b*) hardness of body covering, (*c*) number of legs. (3) Where do potato beetles spend the winter? In what stage? (4) How do potato beetles harm a plant? (5) Why does injury to the leaves prevent potatoes from growing? (6) How may potato beetles be destroyed? (7) Why is it most important to destroy the adults that appear first in the spring?

III. THE HOUSE-FLY

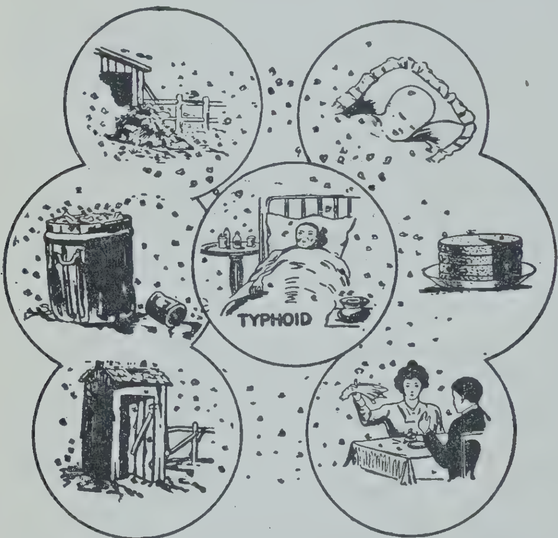
Why flies are dangerous.—We think of lions, tigers, and snakes as the most dangerous animals in the world, and we are careful to keep away from them. There are other animals that do much more harm and cause many more deaths than these. They are smaller animals that live among us and injure us by carrying diseases. The most dangerous disease-carrying animal in Canada is the common house-fly. We have become so accustomed to these flies, however, that we are not offended by their dirty habits.

If a potato beetle or a caterpillar falls into your glass of water, you will probably not drink the water. Yet a fly may alight on the rim of the glass where you are about to put your lips, then run down the inside for a drink, paddling in the edge of the water with its front feet, and you will flick it away and drink the water. Why? Probably just because it happens so often and because other people do the same.

If we compare what is known about the potato beetle with what is known about the house-fly, we shall be able to decide which of the two is more dangerous to our health.

First, try to answer the question, "Where was the potato beetle or the caterpillar before it fell into the glass of water?" We discovered that the potato beetle and the caterpillar are leaf-feeding insects, and we know that the leaves of garden plants such as lettuce, spinach, and cabbage are good healthy food for human beings. The potato beetle and the caterpillar, therefore, are not likely to be very dirty or to have many disease germs upon them.

Now we shall answer the question, "Where was the house-fly before it came to the glass of water to take a drink and to wash its front feet?" To do this we must study the life of the fly. You may have seen a dead animal or a piece of meat with white "maggots" living in it. These maggots are the larva stage of the fly. Those that live in decaying flesh, however, usually develop, not into house-flies, but into the "blue-bottle" fly or "blow-fly."



—Re-arranged from Bulletin of International Harvester Co.

Fig. 181. Flies travel from filth to food. Where did the fly come from that alights on your food? If there is sickness in a neighboring house, might flies bring it into yours? How?

The larvae of the house-fly are found chiefly in piles of manure cleaned from horse-stables, or in garbage or other filth that is left neglected in a pile. Any pile of such material that remains undisturbed for two weeks or more allows the larvae to hatch.

The fly's home is therefore in manure or other filth. From this home the adult goes out in search of food. It is especially fond of sweets, milk, and other foods that we use, and seems able to discover them from a distance. How? On its way to the house the fly alights upon any filth that it sees or smells in order to find whether it would be a suitable place in which to lay eggs (Fig. 181).

Now we know where the fly had come from when it visited the glass of water. Look at the photograph of the

fly's foot (Fig. 182), and decide whether it would be likely to carry any dirt on its feet. Its whole body is hairy also, and filth clings to every part of it. Do you think that the water was fit to drink after the fly's visit? Do you think that it would be safe to buy foods from a store-keeper who allows flies to walk upon them in his store?

In the manure and garbage upon which the fly walks before coming to the house there are swarms of bacteria or germs. These germs are so small that one fly with dirty feet may have many thousands of them clinging to its feet and body. Of the flies that visit us in our homes, some are carrying as many germs as there are people in a large city. Most of them are carrying as many germs as there are people in a good-sized town, and probably there are very few flies that have not several hundred germs on their feet and bodies. Though not all of these are dangerous disease germs, many of them are, and it is always unsafe, therefore, to allow flies to walk over food or anything that comes in contact with it. The house-fly so often carries germs of typhoid fever that it is known also as the "typhoid fly."

Fig. 182. Fly's foot (×15). Is it likely that the fly's feet are clean after it has walked in manure or garbage? There are two sticky pads under the claws with which it can hold on to the window pane. These also carry germs.

One disease germ left by a fly in a pitcher of warm milk may increase to many hundreds in a few hours. When we drink the milk, therefore, it may be as dangerous as though several hundred flies had stepped in it. If it is kept very cold, the germs will not increase. How does a refrigerator keep our food from spoiling?

Stages in the life history of the fly.—In order to protect ourselves against the diseases carried by flies we must know

how they live. To discover their habits we must observe the stages in their life history. Look at the preserved specimens in your school collection and see the egg, the larva, the pupa, and the adult stages (Fig. 183). These are similar to the stages of the butterfly and the potato beetle, but the house-fly develops more quickly than either of these insects. The egg hatches in one day or less. The pointed larva eats ravenously and then passes into the pupa stage, where it rests in an oval brown case. The adult comes out of the pupa case about two weeks after the egg is laid. As it can, in its turn, lay eggs (about one hundred and twenty) when it is two weeks old, there may be several generations of flies in one summer. Calculate how many flies might develop between May 1st and September 15th from the eggs of one female that lives over winter, allowing four weeks from the egg stage of one generation to the egg stage of the next.

Fig. 183. Stages in the life history of the fly. Notice the white eggs under the straw. The light-colored, pointed larvae and the dark oval pupae were also buried in the manure.

Parts of the body.—Examine a living fly in a test-tube plugged with cotton. In this cage you can see it from all sides. Look for the parts that you have seen in other insects. Find first the three main divisions of the body: head, thorax, and abdomen. Notice the very thin, flexible neck. Find the parts attached to the head. Has the fly any antennae? Has it compound eyes? Can you see its mouth parts? Feed it a drop of sugary water and observe how it eats. Notice the soft, thick sucking tube. A fly cannot eat dry sugar; it first moistens it and then sucks up the liquid with some of the sugar dissolved in it.

What parts are attached to the thorax? How many pairs of wings are there? Perhaps you can see with a magnifying glass the little knobs called balancers that take the place of the second pair of wings. How many pairs of legs are there? We have looked at the fly's foot and have seen why it is likely to carry dirt to our food when it comes in from the manure pile. Is the rest of the body hairy also?

You can see that the abdomen is made up of segments like that of other insects, but you will probably have difficulty in seeing the breathing tubes or the ovipositor. Where would you look for these?

How to prevent flies from spreading disease.—What can we do to protect ourselves against the germs carried by flies? Since we know that flies develop in two weeks in manure and rubbish, we know that they will not develop if we clear away all such material every week, or keep it tightly covered. First, then, we should clean up all the rubbish about our homes in which flies might live. This will reduce their numbers. Next, we should kill the wintered-over flies that we find in the house in the spring. Poisons, fly-traps, sticky paper, and swatters are all useful for this purpose. Where there is little food about, flies more readily take poisons and enter traps. Sticky papers catch the germs as well as the flies. The swatter brings death to the last few in the house. If we use all these means of destroying flies, we can greatly decrease their numbers indoors and out. Then, if we keep all our windows and doors well screened, we can, by constant effort, protect ourselves and our families against these carriers of filth and disease.

Question Outline

(1) Why are flies more harmful than other animals? (2) What harm do they do? (3) Are many children killed every year by flies? (4) What causes typhoid fever to spread rapidly? (5) Will the decrease in the number of

horses in cities make it more easy or less easy to check typhoid fever? (6) Why are the feet and other parts of the fly's body very likely to carry germs? (7) Why does it matter if *one* disease germ gets into milk? (8) Compare the stages in the life history of the fly with those of the cabbage butterfly. (9) How many flies might be produced by one fly that lives over winter? (10) Has the fly the same body parts as other insects? What difference is there in the parts attached to the thorax? (11) In what three ways may we prevent flies from spreading disease?

Conclusion.—We have learned from our observation of plants and of animals that many of them are our friends and should be protected while others are enemies against whom we must defend ourselves. We have learned also that, in order to decide which are friends and which are enemies, it is necessary to observe them closely and to learn how they live in all of their stages. When we have come to know them, we may find effective means of controlling our enemies and may give to our plant and animal friends the kinds of protection and help that they need.

Book Two

PART I

AUTUMN STUDIES OF PLANT LIFE

CHAPTER XXV

THREE PLANTS OF THE MUSTARD FAMILY

Introduction.—You have observed closely the flowers of the nasturtium or the sweet pea, and have found their parts (pages 7-9 and 13-14). Now we shall examine and make observations upon several other flowers that differ from the nasturtium and the sweet pea, but are somewhat like one another.

Preparation.—For the first lesson we shall require a plant with flowers like those of wild mustard (Fig. 186, A), garden radish (Fig. 184), or single stocks (Fig. 185). Bring into the classroom enough specimens of one of these plants to provide one for each member of the class. The flowers must be very fresh, otherwise their petals will fall. Keep them in the dark in a vasculum (Fig. 5) or other tight vessel until ready for use. The three plants named above are excellent specimens for these observations because they are plentiful, large-flowered, and hardy. The prairie rocket, the wild radish (Fig. 186, F), the single wallflower, and the cultivated turnip are almost equally good but are less plentiful. (Turnip flowers may be grown by planting in the spring turnip roots saved from the previous year.) Candy-tuft (Fig. 187) and alyssum are good specimens, but their flowers are smaller. If magnifying glasses are used, Frenchweed, other mustards (Fig. 186, C and D), shepherd's purse (Fig. 186, B), false flax, and even peppergrass (Fig. 186, E) may be examined. Plants of the last group should not be used until some of the large-flowered kinds have been examined.

The wild mustard (charlock) plant.—Now let us examine the whole plant. In doing so we shall review the parts that we found in our study of the nasturtium and the sweet pea. What are the main parts of the plant? Find the **root.** Is there one main root (tap root), or is the root made up of a number of small branches or fibres about equal in size (fibrous root)? Has the plant a strong hold upon the ground when all its roots are buried in the soil? Are there many

Fig. 184. Garden radish, a plant of the mustard family. Notice the cross-shaped corolla.

Fig. 185. Garden stock also has the cross-shaped corolla. Notice the double tip of the seed pod. Has it many seeds?

rootlets to collect water and food from the soil? Would the roots arranged end to end be much longer than the stem?

Now observe the **stem.** Is it simple or branched? Is it soft (herbaceous) or woody? Has it any green color like the leaves? At the nodes, or joints, along the stem do you find leaves only, or in some places leaves and branches? Is the stem strong enough to stand alone, or does it climb on other plants?

The water and the soil salts taken in by the roots of plants move upward through *sap tubes* in the stem. Some of the sap tubes run out into each branch and from the branches into the leaves. Water and soil salts are carried

Fig. 186. Plants of the mustard family. A, Wild mustard. B, Shepherd's purse. C, Hare's ear mustard. D, Ball mustard. E, Peppergrass. F, Wild radish.

upward through these tubes to every leaf on the plant. Are there leaves all the way up the stem?

Examine the **leaves** of your specimen. Can you see the *veins* of a leaf? Are they more easily seen on the upper or on the under side? The veins carry soil water and sap in their tubes. Do they also seem to form a framework that stiffens the *blade* or flat part of the leaf and helps to hold it up to the light? The green *chloroph'yll* in the leaves uses the water and soil salts, together with part of the air (carbon dioxide) that is taken in, to make *sugary sap* that feeds the whole plant. To make this food the leaves must have *light*.

Fig. 187. Candytuft, another garden plant of the mustard family.

Some of the sugary food is used in the leaf, some of it goes down through the sap tubes to the roots, some goes to the stem, and some goes to the flowers and seeds. There are therefore two sets of tubes in the leaf veins and in the stem, one set for carrying soil water *upward*, and the other for carrying sugary sap *downward*. Do you think this plant stores much food in its root? In a radish plant the root appears to be well filled with food, but by the time it has reached the flowering stage the root is usually hollow because the food has been used up. What does the plant do with its spare food when it begins to produce seeds? We shall learn more about the roots, stems, and leaves of plants later, in the chapters dealing particularly with these parts.

Now look at the **flowers** of your specimen. Are there many in the cluster? What is their color? Would they be easily seen by passing insects? When you look down upon the flower, can you see that it is shaped like a cross

(+)? Are any of the flowers older than others? Have any of them produced seed pods? Are there any buds on the plant that have not yet opened?

Practical Exercise

Look at the sample of work from a pupil's note-book shown on page 238 for suggestions; then plan a page of diagrams of the plant that you have examined. Lay out the page so as to make spaces for four diagrams and their labelling, as well as for the page title at the bottom. Figure 188 suggests the divisions as they might be laid out in light pencil lines. In the bottom space (*a*) make a simple diagram of the root, showing its shape and how it branches. On this diagram label the primary or main root and the branches. In the second space (*b*) draw a part of the stem showing at least one joint where branches grow. Show on this part of the stem the beginning of a branch and one whole leaf. In the third space (*c*) draw one or more seed pods attached to a short length of stem. In the top space (*d*) show two views of the flower, (1) as it appears from the side, and (2) as it appears when you look down upon the top of it. In this view be careful to show its cross-like shape. This diagram need show only the outside of the flower to give its size and shape. Plan your work as suggested in Chapter I.

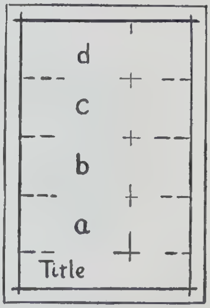
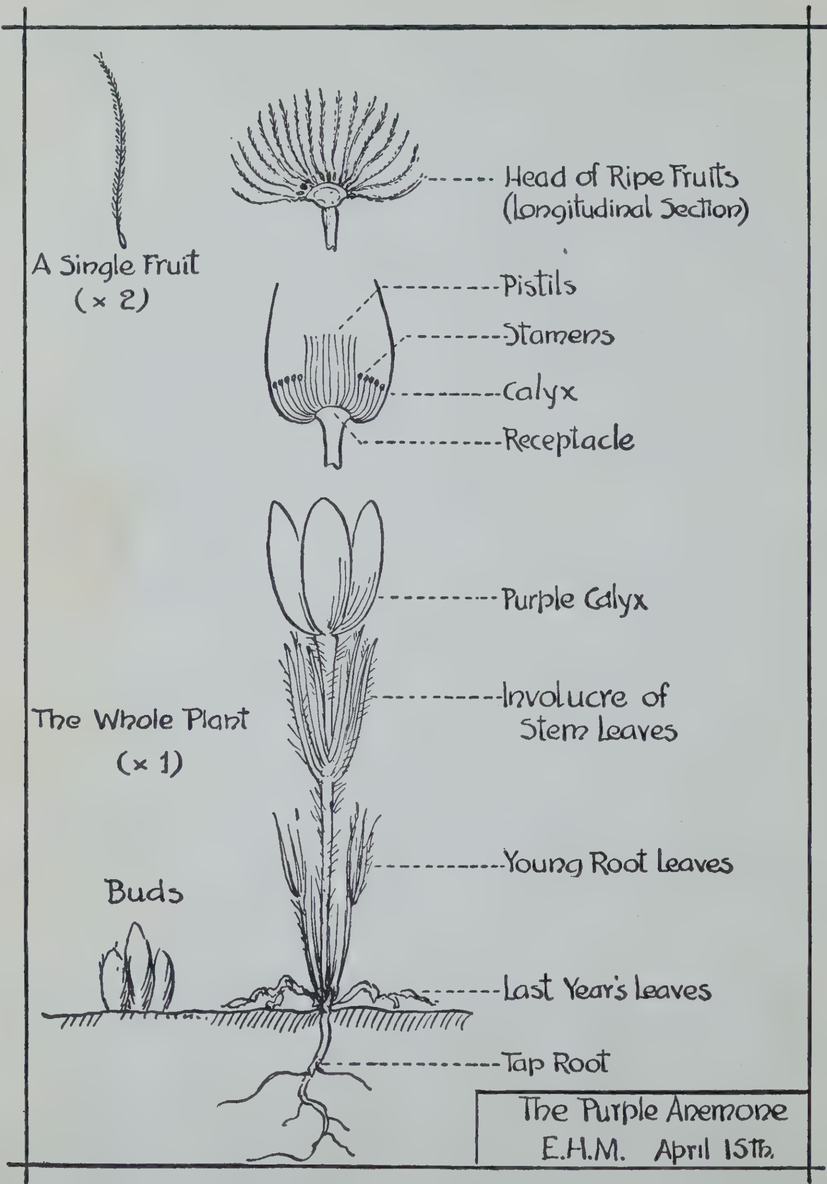


Fig. 188. Page laid out for four diagrams.

In the space to the right of each diagram, print a title and show the size, "× 1" (natural size), "× 2" (twice natural size), etc. We now have a record of what we have seen of the parts of this plant. When the page has been completed, erase the unnecessary pencil lines, and date and initial it. E.H.M. uses printed labels. Do you like them?

Preparation for the next lesson.—For the next lesson we shall require a branch of the mustard or of one of the other plants mentioned. The branch should have upon it some buds, some fresh flowers, and some seed pods. A magnifying glass will help us to see details more clearly. A large glass-headed pin or a dissecting needle with a wooden handle or a pair of fine forceps will help us to gain skill in handling the parts. These instruments are only helpers for our eyes and fingers, however, and we must not expect them to do the work for us. They are not used to make the work easier, but to enable us to do better work.


Head of Ripe Fruits
(Longitudinal Section)
A Single Fruit
(× 2)
Pistils
Stamens
Calyx
Receptacle
Purple Calyx
Involucre of
Stem Leaves
The Whole Plant
(× 1)
Young Root Leaves
Buds
Last Year's Leaves
Tap Root
The Purple Anemone
E.H.M. April 15th.

Parts of the flower.—Now look on your specimen for the flower parts that you have previously found on the nasturtium or the sweet pea. On the outside is the circle of green leaf-like *sepals* making up the **calyx.** Notice how the bud is wrapped up in the calyx. Does this protect the delicate parts against insects, wind, dust, hot sun, or frost? How many sepals are there? Do they remain attached after the other parts of the flower fade?

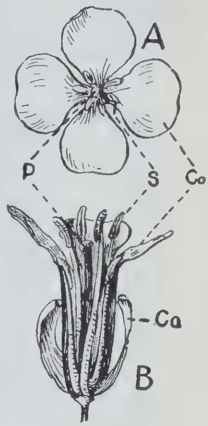


Fig. 189. Mustard flower showing parts. Find on your specimen the calyx, corolla, stamens, and pistil, and compare them with this diagram.

Just inside the calyx find the circle of *petals* making up the **corolla.** How many petals are there? Of what use is the bright color of the corolla? (Are cabbage butterflies attracted to radish flowers in the garden?) Has this flower any perfume or nectar? Of what use are color, perfume, and nectar to flowers? Have all of the flowers the same number of petals? Are they arranged in pairs? The petals soon fall off after the flower has been picked, but when the plant is growing they remain attached until an insect has visited the flower, or until the flower has used its own pollen. Then they fall off. Why are they no longer needed?

Next look into the flower and see the circle of **stamens** just inside the corolla (Fig. 189, A). To see all of them it is best to remove two sepals of the calyx and two petals of the corolla. The needle or forceps will help to remove them without injuring them. Now look in at the side of the flower (Fig. 189, B). Observe again the circle of stamens. How many are there? Are their stalks, or *filaments*, all equally long? Are their pollen sacs, or *anthers*, round or oblong? Find at the centre of the flower circles the **pistil.** Compare its parts—*stigma, style,* and *ovary*—with those shown on page 10. The stigma is sticky. Of what use is it?

Practical Exercise

Fig. 190. Mustard flower from bud to ripe pod. Find these stages on all of your plants of the mustard family.

Before taking the flower apart further, make a diagram of it. Lay out a page as in Figure 188, but leave space *d* somewhat smaller than the others. In space *b* draw the "Side View of Flower with One Side of Calyx and Corolla Removed (× 2)". In this drawing label calyx (sepals), corolla (petals), stamens, and pistil. The end of the stem upon which these flower parts stand is somewhat enlarged and is called the **receptacle.** Show it also and label it in your diagram. It is clear in Figure 189.

We have noticed the bud wrapped up in the calyx. In the top space (*d*) show two or more buds in different stages of growth (× 2). Label the sepals and the petals where they show.

Find a withered flower. What parts of it are falling off? What part is growing larger? What does the pistil form as it becomes older (Fig. 190)?

In space *a* show four views of a seed pod: (1) "Side View", (2) "End View (× 2)", (3) "Cross Section (× 2)" (a cross section is the surface exposed by cutting the pod in two crosswise). In this drawing show the two compartments, separated by a partition and containing the seeds. (4) "How the Parts of the Seed Pod Fit Together". This is best seen in a ripe pod that is opening.

Now remove from the flower the remaining sepals and petals so that all of the stamens may be clearly seen. Notice again the two different sizes of stamens, four long and two short. Remove one of the long stamens and one of the short ones. Lay them out close together with their lower ends standing on the same line. Draw these (× 2) in the left half of space *c* on your page, reserving the right half for a diagram of a pistil. Label the filament (stalk) and anther (sac of pollen) of one of the stamens.

Finally, remove all of the stamens and leave the pistil standing alone on the receptacle. In the right half of space *c* draw a diagram of the pistil (× 2) and label the stigma, style, and ovary. (See page 9.)

Preparation for the next lesson.—We are now ready to compare the plant that we have examined with other

plants. Each member of the class should have three plants of those named on page 233 or other similar kinds. The sets of three need not be all alike; therefore, if each member of the class brings in a supply of one kind, they may be exchanged.

How we make comparisons.—When we compare two or more things, we look for ways in which they are alike. We call these ways in which they are alike *similarities.* We look also for ways in which they are unlike. These are *differences.* When we wish to find all the similarities and differences between two things, we must plan carefully, and look for them in some definite way. Suppose, for example, you wished to compare the numbers of ripe seed pods on two large plants of peppergrass or Frenchweed. You would not attempt to count them by beginning at a certain place and counting at random. You would probably cut off the branches one by one and count the pods on them, removing each pod as it was counted, until you had found the total number on one plant. Then, by counting the pods on the other plant in a similar way, you would be able to make an accurate comparison. To make an accurate comparison you must have some regular plan by which to find the similarities and differences.

In the above example, it is very easy to think out a regular plan, but when we wish to compare whole plants, it is more difficult to make a plan. However, since we have examined the root, the stem, the leaves, the flowers, and the fruits or seed pods of one or more plants, we can use these parts in planning our comparison.

Comparison of three plants.—Examine your three plant specimens, following the plan suggested.

Roots.—Are the roots alike in shape? Has each of them one main root with smaller branches coming from its sides? Are they strong to withstand a pull? Are they similar or different in color?

Stems.—Are the stems of these plants simple or branched? rough or smooth? Can you see any other similarities or differences in their stems,—height? thickness? color?

Leaves.—How are the leaves arranged on the stem, opposite in pairs or alternately? Look at the veins of the leaves. Is there one large vein running along the middle of each leaf? Can you see branches and a network of smaller veins in the blade of the leaf? Are there any other similarities or differences in the leaves? Consider their color, shape, surface, and taste.

Flowers.—Look at the positions of the flowers on the stems of the three plants. Are they alike? Are there buds above the flowers and seed pods below them in each case? Carefully examine the flowers. Do their corollas all show the cross shape (+) that you found in the plant which you examined first? Are the petals alike in color, shape, and arrangement? Is each calyx large or small? How many sepals are there in each calyx? Are they, too, in the form of a cross? Take off the calyx and corolla of all three flowers and look at the stamens. Are the stamens of the three flowers alike or different in number, in size (four long, two short), in shape, and in arrangement? Remove all the stamens after you have compared them and look at the pistils. Are they alike in shape or in size? Look inside the pistils, or in an old pistil that has formed a seed pod. Can you find any seeds? Into how many seed cavities is each pod divided? Is the partition between the cavities thick or thin? How many seeds are there in each cavity?

What we learn from comparing the three plants.—We have found by comparing the three plants that their roots, stems, and leaves are alike in many ways, and that they have only a few slight differences. The flowers, we found, are even more alike than the other parts. They are quite unlike those of the sweet pea or the nasturtium that we

examined, but in almost every detail they are like one another. The peculiar cross shape of the corolla, the peculiar stamens, four long and two short, and the seed pod divided into two seed cavities by a thin partition are found in all three of these plants.

The three plants that you have compared, and others that other members of the class may have compared, are all very like one another and very different from most other plants. They are so much alike that we think that they must be related to one another. When we see people who look very much alike, we say that they probably belong to the same family. Similarly, when we find plants that resemble one another as closely as our three specimens do, we say that they belong to the same *plant family*.

Because there are many mustard plants in this family, and all of its members have a sharp mustard-like taste, it has become known in most English-speaking countries as the *Mustard Family*.[1]

The mustard family includes, in addition to mustards, many other common plants such as radish, stocks, wall flowers, alyssum, Frenchweed, shepherd's purse, and pepper-grass. Many of them are troublesome weeds in cultivated fields and gardens. Let us see if we can discover the reason for this.

Why plants of the mustard family may become troublesome weeds.—We have seen that the plants of the mustard family have buds at the top of their stems, flowers below them, and seed pods below the flowers. The lowest seed pods are formed from the flowers that open first, and they ripen very early in the summer. The plant goes on growing

[1]In other countries the family has other names, and even in our own country it has several other local names such as *Cress Family*. It has, however, only one Latin name or scientific name—*Cruciferae* (from the Latin word *crux*, a cross),—by which it is known the world over. This name reminds us of the cross-shaped corolla, and, whenever it is used, in whatever language, it enables us to know with certainty the family to which reference is made.

taller and producing new flowers and buds for many weeks if the weather is favorable. More seeds are ripening, therefore, every few days from early summer onward.

If the mustard plant is growing in a wheat field, will its earliest seeds ripen and fall upon the ground before the farmer harvests the grain? Do you see why it is very difficult to rid large grain fields of such weeds? Does the habit of ripening its seeds unevenly give the plant a better chance of living from year to year? When conditions are favorable, the plant increases very rapidly, and even when they are unfavorable, it sows a few seeds each week, at least one of which is likely to survive. The indeterminate or "never-ending" habit of flowering, with the resulting uneven ripening of seeds, is therefore an advantage to the plant but a disadvantage to the farmer who is trying to destroy it.

Question Outline

(1) What are the main parts of a plant? (2) What is the difference between tap roots and fibrous roots? (3) What is an herbaceous stem? (4) What are nodes? (5) Where do branches and leaves grow out from the stem? (6) What moves upward through the sap tubes? (7) What moves downward through them? (8) What are the veins of a leaf? (9) What is each of the four circles of flower parts called? (10) What are: anthers, filament, stigma, style, ovary, receptacle?[1] (11) What is the use of the calyx? the corolla? the stamens? the pistil? (12) What becomes of each of them after an insect has brought pollen to the stigma of the pistil? (13) How many sepals, petals, stamens, and pistils did you find in flowers of the mustard family? (14) Make a list of the similarities and a list of the differences that you found between the three plants that you compared. (15) Why do we think that these three plants are related to one another? (16) What is their family name? (17) Do all the seeds of these plants ripen at once? (18) Is this an advantage or a disadvantage to the plant? to the farmer? Why?

[1] Review Chapter II as well as this chapter if necessary.

CHAPTER XXVI

PRESSING AND MOUNTING PLANTS

Introduction.—We have now become acquainted with a number of plants belonging to the mustard family. It would take a great deal of time and would be very difficult to draw diagrams of all of them to show what we have found, but there is another way of keeping on record what we have seen. It is to preserve the plants themselves.

To do this successfully we may store the plants in liquid such as formalin (see Appendix, Sec. 23), or we may press and dry them between sheets of paper and mount them on cards. If they are carefully mounted, specimens are better than pictures. There are in the universities and museums of the world many great collections of pressed plants, just as there are great libraries of books and great collections of pictures. Collectors in different countries often exchange mounted plants with one another. It would be very interesting to exchange a few well-mounted specimens with a class in some other part of Canada or in another part of the world. Pupils in other places would like to see our plants, and theirs would be very interesting to us.

In order to keep a permanent record of the plants of the mustard family that are found in your district, each member of the class should press and mount four plants. Try to include in the class collection all of the wild and cultivated plants of the family that grow in your district. Methods of pressing and mounting plants are described in the following sections.

How plants may be pressed.—Plants that are carefully

dried may be kept indefinitely. In order to retain the colors in the plants, and to prevent them from turning black with decay, they must be dried as quickly as possible. This is done by putting them between sheets of paper that will absorb moisture quickly. To prevent the parts of the plants from shrivelling or wrinkling, they must be pressed between the sheets of paper with a force sufficient to hold them flat but not great enough to crush the more delicate parts. For absorbing the moisture we may conveniently use newspapers. Paper from the colored sections of newspapers or from magazines is not suitable for the purpose because it does not absorb moisture rapidly enough. A few bricks, or stones of about the same weight as bricks, are heavy enough to hold the plants flat while being pressed.

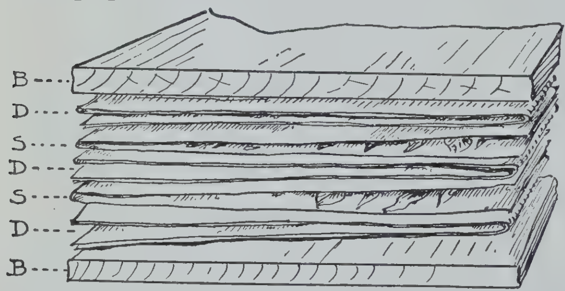


Fig. 191. Diagram to show arrangement of specimen sheets and driers in the plant press. B, Boards. D, Driers. S, Specimen sheets.

A plant press may be made very easily. First cut two flat *boards* 24 inches long and 10 inches wide, one to be placed under and the other over the plants while being pressed (Fig. 191). This is a very convenient size as it is half that of a newspaper page. Separate the sheets of a newspaper and fold a number of the double sheets lengthwise. (Each double sheet has four pages of print on it.) A double sheet, when folded, makes four ply of paper. These folded sheets we may use as *driers* to absorb the moisture from the plants. In the same way, fold half as many single sheets. (Each single sheet has two pages of print on it.) In these we may place the specimens to be pressed. We call them *specimen sheets.*

When an entire class is mounting specimens, each member should bring to school at least two driers and one specimen sheet. If a number of plants are to be pressed, more paper may be required. As it is important that the plants should not commence to wither and wrinkle before being put in the press, it is essential to have the paper on hand and folded before the plants are collected.[1]

In selecting plants to be pressed, keep in mind that they are to be mounted in folders on a space not larger than 4½ inches wide and 12 inches long. If a plant that you wish to press is so large that it will not fit this space, it may be necessary to mount only part of the root, stem, leaves, and flowers or fruit. If any of these parts is very thick, some of the material should be carefully cut away from the side that will be attached to the sheet on which the plant is finally to be mounted. If this is not done, the thin parts of the plant, such as the leaves, cannot be held flat while they are drying in the press. The roots must be free from soil. If necessary, they should be carefully washed in a pail of water or under an out-door tap.[2]

After you have collected and prepared your specimens, arrange them in the folded specimen sheet so that all parts lie flat. Do not allow the leaves and flowers to overlap. Put your name on the sheet. Then put a drier on one board of the press and place upon it your specimen sheet containing the specimens. It is best to put the fold of the specimen sheet towards one side of the board and the folds of the drier towards the opposite side (Fig. 191).

On your specimen sheet lay a drier with the fold facing the same way as the fold of the first drier. As many as forty specimen sheets with driers may be arranged altern-

[1]If the plants are collected at a distance, or if for any other reason they cannot be placed in the press immediately, they should be stored in a vasculum (Fig. 5), in a tin pail tightly covered, or in damp newspaper.

[2]Do not wash soil into a sink. It will stop the drain.

ately in this way. Carefully pile all the sheets with the folds of all the driers facing one way, and place on top of them the other board of the press. Then, either cover the board with a layer of bricks placed on edge, or an equal weight of other materials, or strap the press tightly. The pressure holds the plants flat and keeps the paper pressed against them to absorb the moisture.

After twenty-four hours remove the top board, place it beside the press, and lay upon it a fresh drier. Then pile upon this alternately the specimen sheets containing the plants and fresh driers, laying aside the driers that have become damp. Place the other board on the top of the pile and apply pressure again. If the leaves show signs of wrinkling, the pressure should be increased. Place the discarded driers where they will dry out again ready for use two days later.

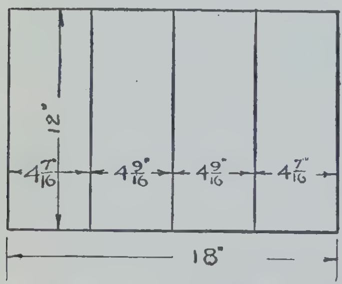


Fig. 192. Sheet of tag Manilla paper laid out for folder.

Change the driers a second time at the end of two days, and a third time two days later. The plants should now be left in the press for at least two days and should be stored there until you are ready to mount them.

Mounting pressed plants.[1]—In large collections the plants are mounted on large flat sheets (usually 11½″ × 16½″), but for class use a folder is more suitable. Folders for mounting the plants that you have pressed may conveniently be made of tag Manilla paper[2] as follows: Mark a 12″ × 18″ sheet into four panels as shown in Figure

[1]Note to the Teacher.—If the season is advanced, the plants may be left in the press and the mounting done after all other autumn work has been completed.

[2]This is the paper of which luggage tags are made. It is advisable to order sheets 12″ × 18″ because the large sheets kept in stock by dealers cut to this size without waste. The "350 pound tough surface" quality is a suitable grade to order.

192, making the outer panels about ⅛ inch narrower than the two inner ones, so that the folder will remain shut more readily. Rule two light pencil lines across the bottom of the sheet upon which to place labels. Then fold the sheet along the vertical lines into the four panels as shown in Figure 193. Make the folds over the edge of a ruler or of the desk so that they will not break irregularly. Fold the outer ends inward and then fold inward at the middle. When time permits, the outside cover may be marked with a title such as "Plants of the Mustard Family", the collector's name, and other information or ornament.

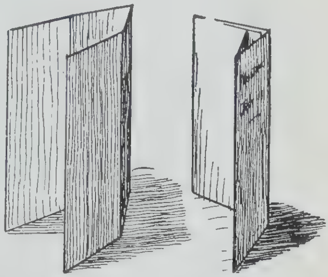


Fig. 193. Folders for mounting plants completed.

After the folder has been made ready, a plant should be taken from the press and carefully placed in a panel. The root, stem, leaves, flowers, and fruits (seed vessels) should be shown. If the whole plant is too large for the panel, use suitable portions to show the various parts.

For fastening the specimen to the folder, you may use small strips of brown paper gummed tape cut crosswise. To hold the plant securely in place, two or more strips should be stuck across the main stem and one on each branch. A neater method is to sew the specimen to the folder, tying the thread on the back of the card after each stitch and covering the knot with gummed paper tape. Very fine wire is a convenient substitute for the thread, holes being made for it with a pin. Very thin leaves may require to be stuck to the card with glue to hold them flat. Mount one plant of the mustard family in each of the four panels and complete their labelling. Show clearly the *place* and *date* of collection, the *collector's name*, and the *name of the plant*, if known.

In some cases, cards may be found more suitable than folders. For the school collection mount one set of good specimens on $6\frac{1}{2}'' \times 8\frac{1}{2}''$ cards under glass or clear celluloid, making mounts similar to those used for pictures. (See Appendix, Sec. 6.) It is best to place on these cards a thin layer of white cotton batting;[1] then lay the plant on the cotton and cover tightly with the glass, binding the edges with tape. The cotton holds any parts in place that might otherwise fall off with handling.

When you have made one complete mount and labelled it, you have begun a collection that may grow to be a large one, containing all the kinds of plants of your district or of your province. Such a collection would be very interesting and very valuable.

[1]This is sold in rolls about $6\frac{1}{2}$ inches wide and should be ordered in this width so as to fit neatly under the glass.

CHAPTER XXVII

PLANTS OF THE GRASS FAMILY

Introduction.—When we speak of a "grass plant," we do not mean some blades or leaves of grass only; we mean a plant with a root and a round stem bearing flowers and seeds as well as leaves. Grass that has not been cut since the spring will show all of these parts (Fig. 194).

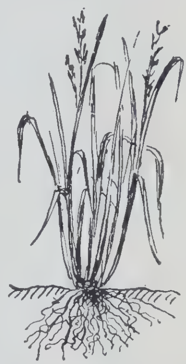


Fig. 194. A grass plant has roots, stem, leaves, flowers, and fruits. "Blades" of grass are the leaves.

Preparation.—Each pupil should bring into the classroom a grass plant with one or more tall round stems bearing clusters of flowers or seeds. Figure 195 shows some grass plants that will help in naming the specimens. To get the root, a piece of turf may be cut out with a knife and the soil shaken or washed from the roots.[1] The roots of other plants should be disentangled carefully from those of the one grass plant. The specimens used by the class need not all be the same kind of grass but should include a number of important kinds, such as timothy, brome grass, rye, wheat, oats, and barley (Fig. 195). One fairly large piece of sod or turf with tall grass upon it should also be brought into the classroom, fitted into a pan, a large plate, or a shallow box, and kept watered so that the grass will continue to grow. It will serve to show how the grass plants live among their neighbors.

Comparison of grass plants.—Let us now compare the various kinds of grasses that we have before us.

Roots.—Have the plants all fibrous or finely branched roots, or have some a single tap root with smaller branches? Some may be found to have underground stems that look somewhat like tap roots, but it can be seen that these are

[1]Wash it out-of-doors in a pail, not in a sink where soil would stop the drain.

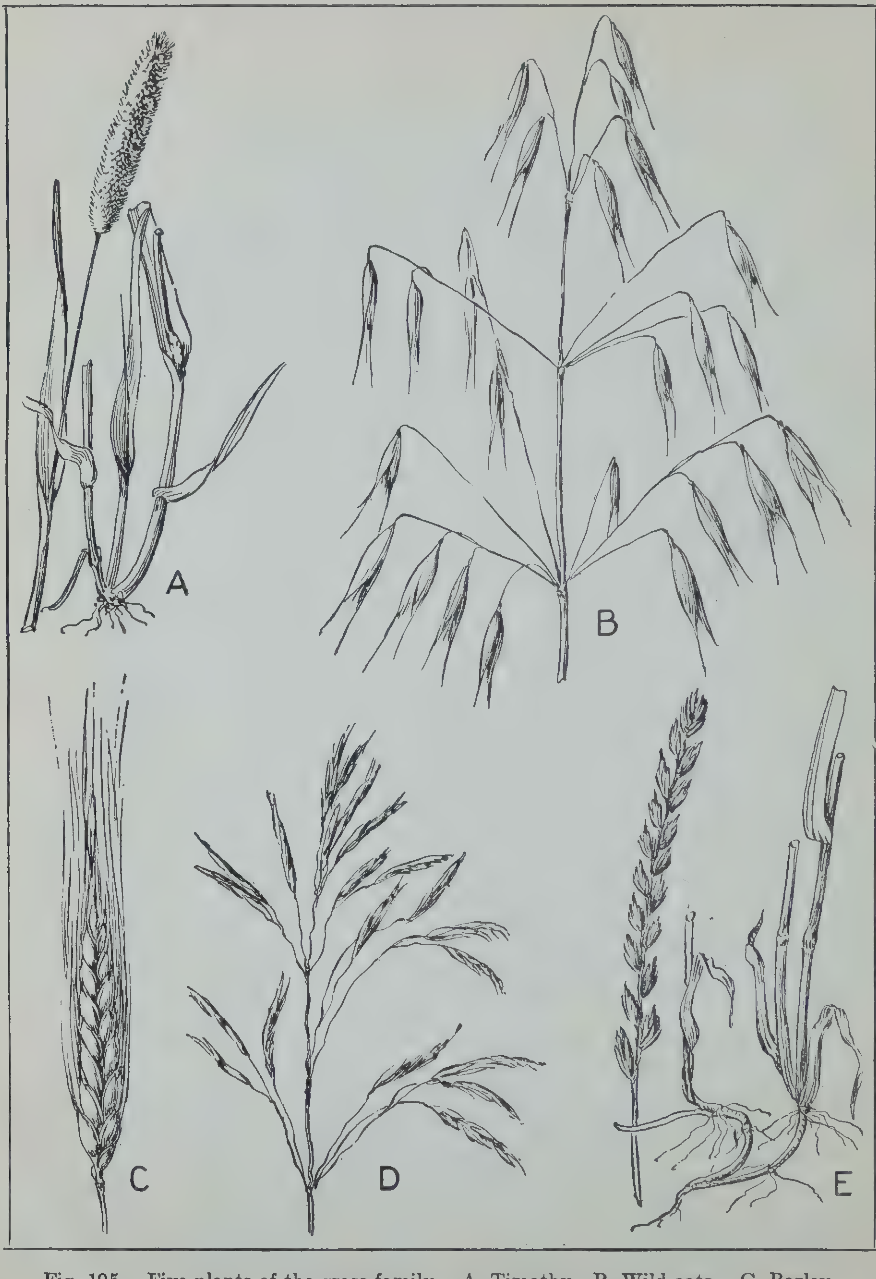


Fig. 195. Five plants of the grass family. A, Timothy. B, Wild oats. C, Barley. D, Brome grass. E, Couch grass.

really stems because they have nodes, or joints, with scale-like leaves upon them. Roots have no nodes. In collecting your specimens did you find that the roots of grass plants have a strong hold upon the ground? Is this important when animals are biting off part of the stems and leaves for food?

Stems.—Next look at the stems of your grass plants. You probably find some short stems bearing leaves only, but there are also some tall, slender, hollow stems that lift the clusters of flowers or seeds high up to the wind and to the light. These stems or "straws" are strong enough to carry their load of seeds, and yet, because they are hollow, very little food is sufficient to enable them to grow quite tall. They are also very flexible, so that they bend easily instead of breaking.[1] Have you seen the "waves" made by the wind in a field of grain or of long grass? "Dark hollows seem to glide along and chase the sunny ridges"[2] as the slender stems bend before the wind and rise again to the upright position. Can you see on these tall stems the nodes and the sections of stem between them?

Leaves.—Are the leaves of the grass plants like other leaves? Do you find on any of the grass leaves a broad, flat *blade* with a network of *veins* and a leaf stalk, as we have found in other leaves? What is the shape of the blade in grass leaves? Do the veins run from end to end of it? Is there a vein parallel to each edge? Do you see that, instead of having a petiole, the lower part of each leaf is wrapped tightly around the stem, forming a *leaf sheath* (Fig. 196)?

Can you see in what way the leaf sheath is useful to the plant? Carefully unroll a leaf sheath and remove it from the

[1]To realize how very strong the grass stems are, think of a tree one hundred times as thick and one hundred times as tall as a wheat plant. How large would it be? Could such a tree stand even with a stem of solid wood?

[2]From *The Prairies* by William Cullen Bryant.

stem. At what point on the stem was it attached? Does the part of the stem that you have uncovered appear as strong as the part that was not covered by the sheath? While the grass plant is young, these covered parts of the stem are very soft, being supplied with a great deal of sugary sap from the leaf. This sap enables them to grow rapidly and lengthen the stem. The leaf sheath supports and protects these softer parts of the stem while they are growing. Would the sheaths on the lower part of the stem help to prevent it from bending too sharply, and help it to spring back after bending?

Fig. 196. Grass leaf showing sheath and blade.

How are the leaves of the grass plant arranged? Do you find the leaves very near the top of the plant? Are the upper sections of the stem longer or shorter than the lower ones? Since there is a leaf at each node, or joint, are there more leaves on the upper or on the lower part of the stem? Look at the grass on the piece of turf. Can the sunlight shine down between the plants to reach the lower leaves? The grass flowers do not attract insects but depend upon the wind to carry their pollen and their seeds. Is any advantage gained by having the flowers and seeds raised well above the leaves?

Fig. 197. Timothy grass in flower. Clusters of purple stamens are seen hanging from the flowers.

The flowers of the grasses (Fig. 197) are very different in outward appearance from those of the nasturtium, the sweet pea, or the mustard plants. Most of the grass specimens found in the autumn have passed the flowering stage, but even in the summer, when the flowers are open, we do not see any brightly colored corollas. Instead of calyx and corolla, the grass flowers have protecting scales of *chaff*.

Find the chaff on your wheat, oat, and barley plants, and on the wild grasses. The flowers of grasses produce stamens and pistils as the sweet pea does, but these parts can be seen for only a short time. We shall find them later on a very large grass plant—the corn.

One other important point that we should observe about the grass plants, though it can be seen only by watching plants that are growing, is their method of ripening their seeds. On any grass plant the *seeds are all ripened at about the same time.* In this respect the grass plants are very different from the mustard plants. On the plant of wild mustard, you will remember, we observed at one time ripe pods, flowers, and buds. This shows that, unlike the grass plants, they ripen their seeds at various times throughout the summer.

Practical Exercise

Lay out a page as shown in Figure 198, having spaces for three diagrams of your grass plant specimen. In the bottom space draw a diagram of the "Fibrous Root of .... Grass". In the middle space draw the middle part of the plant showing a node, or joint, a leaf blade, and a leaf sheath. In the top space show the seed cluster at the top of the stem. Label all parts shown in your diagrams.

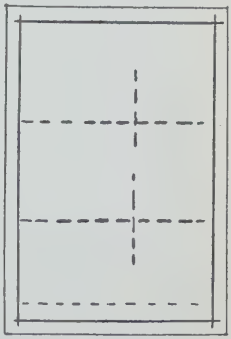


Fig. 198. Page laid out for three diagrams.

We have now examined a number of grass plants and observed their roots, their stems, their leaves, and the clusters of seeds that remain upon them in the autumn. These important parts, we have found, are very much alike in all the plants that have been brought into the classroom. We have learned, also, that the grass plants resemble one another in their habit of ripening all their seeds at about the same time. We shall see later why this is important.

When we look for differences among the grass plants, we find that there are very few. Even the seed clusters that seem to differ from one another are not as unlike as they appear. In barley, the cluster is very close and compact, forming a "head" or "spike," while in oats the cluster is loose and open (Fig. 195). In both of these, however, there is a central stalk with branches along its sides which carry the grains. The branches in one are longer than the branches in the other. Learn to recognize the grasses shown in Figure 195, and the other kinds that are common in your district.

All the grass plants are so like one another and differ so much from other plants that we have reason to believe that they are related to one another. This great group of related plants is called the *Grass Family*.

Why grass plants are important to people.—Let us see why the plants of the grass family are more valuable to us than are the plants of the mustard family or others. The seeds or grains of each grass plant, we have learned, all ripen at about the same time. Therefore, when grass plants such as wheat or oats, growing in a field, are of about the same age, all the grain in the field will be ripe at about the same time. It would be very difficult to harvest the grains if they ripened a few each week all through the summer, as do the mustards, but, since they all ripen at once, the whole plant can be cut and the grain threshed out of it. Because *grass plants ripen their seeds all at one time*, and are therefore easy to harvest, they are especially suitable for us to grow as food plants.

The grass plants provide great quantities of very rich food for people the world over. Each plant produces many grains, and in each grain there is a generous store of food for the young plant within it. It is this food that we prize so highly, and that makes the grasses the most valuable food plants of the world.

The names of some of the food grains are very familiar to us. We should all be able to name the grains growing in our fields when we see them. Mount some good plants of wheat, oats, barley, and rye for the school collection so that everyone in the class may know them.[1]

Wheat, *oats*, *barley*, and *rye* are the most important food grains grown in Canada. What foods are made from wheat? Rye is used for making bread in many European countries. Do we eat oats and barley? These two grains, together with corn, which grows best in a warmer climate than ours, are important food grains for domestic animals as well as for people. In what forms do we eat them?

Fig. 199. Rice is a member of the grass family. It feeds more people than any other plant.

In India, China, and eastern countries *rice* is the most important grain food (Fig. 199). It is, in fact, the only plant that grows food rapidly enough and surely enough to supply the needs of the people where the population is very dense and where food cannot be purchased from other countries. More people depend upon rice than upon any other grain. What follows in Central China if the rice crop fails? Why should we not starve if our wheat crop were to fail?

Fig. 200. Sugar cane plant. What part of the plant contains the sugar?

The grains are not the only parts of grass plants that are useful for food. The stems and leaves make excellent food for animals. We have all seen horses, cattle, and

[1]For long specimens such as these, dust-proof cases may be made from celluloid similar to that used for automobile curtains. (See Appendix, Sec. 15.)

other animals biting off the stems and leaves of growing grass plants, leaving the roots in the ground to send up new stems and leaves. Some grasses, such as timothy and brome grass, are cultivated for hay, and wild grasses, such as red-top, rye-grass, "slough grasses," and others are cut for the same purpose. Almost any wild grasses are useful as hay, even those that have become troublesome weeds in our grain fields.

Fig. 201. Bamboo is a giant grass plant. Its stem grows larger than the stems of some trees.

Are any important foods obtained from grasses other than those that we have already mentioned? *Sugar cane* (Fig. 200) is a grass plant somewhat larger than corn. It provides a large part of the world's supply of sugar. From what part of the plant does the sugar come? What is molasses?

While food is their most important product, the plants of the grass family serve many uses. What are our summer hats made of? Common brooms and whisks are made from *broom corn*, a grass plant that is somewhat like sugar cane but smaller. The same plant is used in eastern countries for making baskets, mats, toys, and other useful or ornamental articles. "Grass" mats and "grass" furniture are made sometimes from grasses and sometimes from other grasslike plants. *Bamboo* (Fig. 201) is a giant grass that is useful in a multitude of ways, especially to people who live in the regions where it grows. Where large bamboo stems can be obtained easily, they are used for

Fig. 202. Bamboo is used for building houses. Would this roof keep out rain?

making furniture, for building houses, and for many other purposes (Fig. 202). Even in Canada you have seen the stems of bamboos put to various uses. Name some of them. Read about bamboo in an encyclopaedia or other reference book.

We have seen that the plants of the grass family provide a large proportion of the people of the world with their most important foods, as well as with food for their domestic animals, and that they also serve a number of other uses. We may say truthfully, therefore, that the grass family is the most important of all the families of plants.

Practical Exercise

We have mentioned the more common uses that people make of the plants of the grass family. You may have heard or read of other uses, the thatching of roofs, for example, or the making of the grass raincoats used in Japan. It is a good plan to keep a scrap-book or a collection of pictures mounted under glass, to which you may add new pictures from time to time, illustrating uses of the grass family to people. Build up a school collection or one of your own.

Where the grasses grow the people live.—Let us see where the plants of the grass family grow and whether the distribution of the people of the earth bears any relation to that of the grasses. Are the great grass lands of the world in the torrid, the temperate, or the frigid zones? Are they on mountains or on the great, flat plains? Consider the great plains of North and South America, of Australia, Asia, Africa, and Europe. These are the homes of the grass plants. Are not these great grass lands also the homes of great numbers of the people of the earth? Many people, of course, live in cities by the sea where they engage in the trade coming from or going to other countries, but the great plains of the continents are the homes of most of the people as well as of the grasses from which they obtain their foods.

Question Outline

(1) Of what advantage to the grass plants is their strong hold upon the ground? (2) From observing the piece of turf brought into the classroom do you think there are many plants of grass on a square foot of grass land? (3) Describe the roots and the stems of grass plants. (4) What are the advantages to the grass plants of the tall hollow stems? (5) Describe the leaves of the grasses and explain the use of the leaf sheath. (6) What is the advantage to the plant of having fewer leaves on the upper part than on the lower part of the stem? (7) Why do grass plants need to grow tall? (8) Do they attract insects? (9) Why is it important to people that grasses ripen all their seeds at about the same time? (10) Make a list of the uses of grass plants to people and another list showing the names of the grass plants that are used for each purpose. (11) Where are the great grass lands of the world? (12) Can you suggest one reason why a large proportion of the people of the earth live on the grassy plains?

CHAPTER XXVIII

THE CORN PLANT

Introduction.—In Chapter XXVII we learned of a great family of plants called the Grass Family. While most of the members of the grass family that grow in this country are small, one of them, the corn, may grow to a height of several feet. Because most grasses are small and have inconspicuous flowers, it is difficult to study them. The corn, however, affords us a good opportunity to learn more about this important family.

Preparation.—(1) Bring to the classroom whole corn plants with tassels, cob, and root. There should be one whole plant for each group of four pupils.[1] After these plants have been examined, they may be put away in the school collection for future use.

(2) Each member of the class should also be provided with a piece of stem having two nodes, or joints, with leaves attached, and a similar piece of stem split lengthwise so that the inside may be seen (Fig. 204). The stems split lengthwise, if green, should be put in 3 per cent solution of formalin when not in use so that they will not dry out. They may also be preserved permanently in liquid for the school collection.

(3) For a study of the flowers of the corn, each group of four pupils should be provided with a tassel and a cob covered with leaves (the husk) and having the silk still attached. If these are taken from plants that have developed late in the season, the flowers in the tassel and cobs will be in the stage of development in which the parts may be seen.

(4) For the school collection, with a sharp knife or a pair of scissors split the husk of a cob of corn lengthwise down two sides and remove it from one side of the cob, being careful not to pull off the silk. Preserve the cob in liquid (see Appendix, Sec. 23) in a tall bottle or sealer.[2]

[1]These may be used for different classes if necessary.

[2]For large classes several cobs should be preserved. It is important that this should be done because it is often difficult to obtain fresh specimens in the late autumn. For the same reason, tassels showing the fresh stamens should also be preserved. Put these in liquid also, as suggested on page xvii.

In what ways does the corn resemble other plants of the grass family?—Let us examine each part of a corn plant to find out in what ways it is similar to grasses that we have already studied. We may begin by examining a corn plant that has had none of its parts removed.

The root.—Is the root made up of many fibres arising from the bottom of the stem? Do they appear to have much food stored in them? Does the root of the corn resemble that of other grasses (Figs. 194 and 203)?

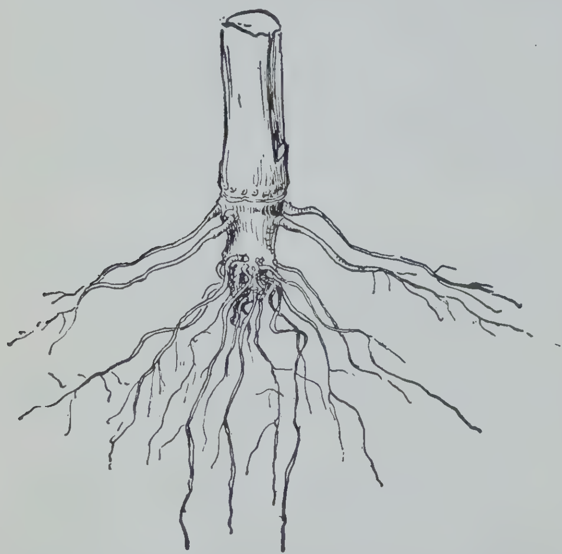


Fig. 203. Root of corn plant. Is this a fibrous root? Notice the extra supporting roots growing from the stem.

How long does the root live? Is it soft, or "herbaceous," or is it woody? Would the roots of a corn plant that is five or six feet tall need to have a strong hold upon the ground in order to anchor the plant? Look for several extra roots growing from a node of the stem near the surface of the ground and reaching downwards. Just as guy ropes may help to hold a tent pole upright or as guy wires may help to support a telegraph pole, so the extra roots that run from the corn stem down into the ground aid the *fibrous roots* of the plant in supporting the tall stem.

The stem.—Remove one of the lower leaves from around the stem. Measure the diameter of the stem and its total height in inches. How many times as great as its diameter

is its height? Have other members of the grass family that you have studied slender, tall stems? (See Figure 195.) Are there any branches on the stems? Look for some that have developed into *ears*[1] of corn. Does the main stem seem to be pressed in on the side facing this branch? Is the arrangement of the leaves on the stem "opposite" or "alternate"? What is found on the upper end of the stem? What grows from the sides of the stem besides leaves?[2]

Fig. 204. Stem of corn. Find the nodes, internodes, pith, and bundles of sap tubes.

Now examine the short piece of stem that has been split lengthwise. Is the stem, with the exception of the parts facing branches, round? Has it *nodes*, or joints, and *internodes*, or sections between the nodes (Fig. 204)? Is the outside of the stem smooth, or is it rough like the bark of a tree? Is it hard? Is the central part of the stem hard like the outside? It is in this central "pith" of the corn stem that the sugary sap of the corn is stored. At the first opportunity, obtain a piece of fresh green corn stem, cut out some pith from an internode, and bite it to squeeze out some of the sap. Does it taste sweet? It is from the sugary sap stored in the pith of the sugar cane stem that we get a great deal of our sugar.

Rub the cut end of the corn stem lightly with your finger. Can you see the ends of numerous bundles of sap tubes that run lengthwise through the pith of the stem? Look for these on the split surface also. These are the sap tubes that carry soil water up from the root to the leaves and other parts of the plant, and carry sugary sap, manufactured in the leaves, to all other parts of the plant.

[1]The ear of corn consists of the short branch bearing the cob with the *grains* upon it and the *husk* of leaves around it.

[2]As the whole plants will not be further required, they may be collected and stored in the school collection.

Were the stems of other grasses that you have studied hollow or solid between the nodes? Does corn resemble most grasses in this respect? Unlike that of most grasses (wheat, for example), the stem of corn is not hollow between the nodes. Sugar cane, another member of the grass family, is similar to corn in this respect. In most grasses, the bundles of sap tubes, through which water and soil salts are taken up, are found only near the outside of the stem. There is no pith at the middle of the stem, which is therefore hollow. With this exception, the stems of corn resemble those of other grasses.

Fig. 205. Leaf of corn showing blade and sheath. Where is the leaf attached to the stem?

The leaves.—Examine the leaf of a corn plant attached to a piece of stem. Is the blade of the leaf attached to the stem at the point where it meets the stem, or does the leaf run down the stem, forming a sheath about it? Is the leaf attached to a node, or to an internode? Is it attached all the way round the stem? Is one side of the sheath split? Does this sheath help to strengthen the slender stem of the plant? Does the shape of the blade of the leaf resemble that of other grasses? Which way do the veins run in the leaf (Fig. 205)? At the place where the blade joins the sheath, can you find a little collar extending upward from the sheath for a very short distance all around the stem? This collar prevents rain water from running down between the stem and the sheath. By examining the roots, the stems, and the leaves of corn plants we have seen that they resemble those of other grasses. Now we shall examine the flowers.

The flowers with stamens.—Now let us examine the "tassel" at the top of the corn plant. Look at one branch of the tassel. Does it seem to have little clusters of small chaff-like leaves growing on it? Are they arranged in rows? Each little cluster usually contains four flowers, two wrapped in scales on a short stalk and the other two wrapped in scales but without a stalk. Of these four flowers you will probably find only one open. This one will have three stamens hanging from it (Fig. 206). If your corn plant is old, there may be no stamens hanging from the flowers. Look for them in Figure 206 and on the tassels preserved in liquid in the school collection.

Fig. 206. "Tassel" from top of corn plant, showing stamen flowers. One cluster of four flowers is shown enlarged.

What is the shape of each anther? What is its color? Does it contain pollen? If you have an anther that is opening, shake out some of the pollen upon a dark surface. (You can see it best with a magnifying glass.)

Remove the leaf-like scales from around the stamens. Have they bright colors like the petals of other flowers? Do you find any pistils in these flowers? Examine flowers from different parts of the tassel to see whether they are all alike.[1]

[1]Occasionally you may find the central tassel developing somewhat like an ear, with pistils, but this is unusual.

While each little flower of the tassel has three stamens, no pistil develops in it. The tiny scales around the stamens have little resemblance to the petals and sepals of other flowers, although they protect the stamens in the same way that petals and sepals do.

Fig. 207. Ear of corn with half the husk removed. This is a cluster of pistil flowers.

As there are no bright colors in the tassels to attract insects, upon what may the plant depend to carry its pollen? When each stamen flower develops sufficiently, the anthers are pushed out from between the scales by the filaments, allowing the pollen to fall out. It is so light that the slightest breath of air carries it away.

The ear of corn.—Carefully examine the ear of corn. It grows on a short branch coming out from the side of the main stem of the corn plant. Look for the broken end of this branch on your cob. The leaves of this branch grow around the cob. They form the **husk** of the ear of corn. The blade of each leaf is very much reduced in size. Notice whether every leaf in the husk has a blade as well as a sheath. The sheath only of each leaf grows large and protects the cob within.

With a pair of scissors, a sharp knife, or a razor blade, cut the husk lengthwise down two sides, being careful not to cut into the grains of corn, and carefully remove all the leaves from one side of the cob (Fig. 207). Do not disturb the "silk."

The flowers in the ear.—How are the grains arranged on the cob? Like each branch of the tassel at the top of

the corn plant, the cob is a branch bearing numerous flowers arranged in rows. Does each flower look like a stamen or like a pistil? In the tassels, only the stamens develop; in the ear of corn, only the pistils develop. Pull out two or three of the pistils, or young grains. Do you see little leaves like chaff at the bottom of the grains, as you found them in the tassels at the bottom of the stamens? You have perhaps had them stick between your teeth when eating corn from a cob. Each group of tiny leaf-like scales, together with a pistil, forms one *flower*. There are many such flowers on one cob. On the half of the cob that is uncovered count the number of flowers in one row; count the number of rows; then estimate how many flowers there are on the cob.

What is attached to the *ovary* of the pistil? Is each of these threads shiny, like silk? How many tips are there on each thread? Hold up one of these threads to the light to see if there are tiny hairs upon it. What must be brought to the pistil of a flower before it can develop seeds? Do you think that pollen might be caught by the hairs on the silk threads? What part of a pistil receives the pollen in flowers? What is the name given to the stalk that holds up this *stigma*? While the long silk thread resembles a style or stalk, it is in reality a long stigma. In order to produce seeds, these flowers, since they have no stamens of their own, must obtain pollen from the stamens of other corn flowers. Where are the flowers on the corn plant that have stamens and produce pollen? Since corn pollen is carried chiefly by the wind, what advantage is it to each pistil on the cob to have a large stigma?

How the pollen of the stamens reaches the pistils.—A little pollen may be carried by insects, but most of it is carried by the wind from the stamens to the pistils of the corn. When the pollen falls out of the stamens at the top of the corn plant, it may fall down on the pistils of the same corn

plant, or it may be blown away by the wind and alight on the pistils of other corn plants. Better grains of corn develop when the pistils receive pollen from the stamens of another corn plant than when they receive pollen from the plant on which they are growing. Will the fact that the stamens and pistils grow on different parts of the plant make the pistils less likely to receive pollen from the plant on which they are growing? Since pollen is carried by the wind, would the stigmas be more likely to receive pollen from another plant if the corn were planted in a long single row or if it were planted in a patch? Why? Since our winds usually blow in an easterly or a westerly direction, would corn planted in a single row running north and south be less likely to be pollinated than corn planted in a row running east and west? Why?

How the flowers of the corn differ from those of other grasses.—From our study of the corn we have found that its roots, its stem, and its leaves resemble very closely those of other grass plants. Their flowers, too, are similar in all respects but one: while in most grasses the stamens and pistils grow in the same flower, in corn the stamens grow in the tassel flowers at the top of the plant, and the pistils develop in the ears lower down on the stem.

The flowers of corn and other grasses differ from the flowers of plants of the mustard family and others in being without a showy corolla to attract insects.

Question Outline

(1) How do the roots, the stem, and the leaves of corn resemble those of other grasses? (2) Where are the flowers that produce pollen? Where are those that have pistils? (3) What parts did you find in the tassel flowers and in the cob flowers of corn? (4) How is the pollen carried from the stamen flowers to the pistil flowers? (5) What is gained when the pistil receives pollen from another plant? How does the separation of the flowers on the corn plant make this more likely?

CHAPTER XXIX

THE SUNFLOWER FAMILY

Introduction.—Having examined plants of the mustard family and of the grass family, we can give at least the family names of many of the plants that we see out-of-doors, both wild and cultivated. A third family to which many of our common plants belong is the sunflower family. When we know the mustard family, the grass family, and the sunflower family, we shall be able to place in their proper families more than half of the common plants of autumn.

Preparation.—For observation of the parts of the sunflower head in the next lesson, bring into the classroom small newly-opened heads of cultivated sunflowers. Split the stem and cut part way through the head from below; then draw it apart carefully. Provide each member of the class with one-half of a head as shown in Figure 208. The parts may be cut smaller if necessary.

The flower head of sunflower.—Examine the specimen of sunflower head. Looking at the cut surface, you find a large number of little seed-like parts. Each of these is developing into a little dry fruit. Carefully remove one or two of those that are near the outside of the head, keeping their upper parts undamaged, and examine one of them. Does it look like a little flower? Find the corolla. Its petals are joined together, forming a tube with the points of the five yellow petals showing at the top. Look for the two branches of the stigma of the pistil extending above the top of the corolla. Do you think that the part that you have removed from the head is really a little flower? Are there many little flowers in the head?

All of the little flowers in the head do not open at the same time. Some of those at the middle of the sunflower head are only in the bud stage (Fig. 208, C). Those with the corollas open and the dark brown anthers of the stamens extending above them (Fig. 208, D) are a little further out. Just outside these are several rows of flowers in which the stamens have withered, and the pistil with its two-branched stigma has come up into view (Fig. 208, E). It was probably one of these outer flowers that you removed from the head. It is easy to see the corolla, the stamens, and the pistil on these little flowers, and, if you look closely, you may find the very small calyx. With the help of Figure 208, G, find all of these parts on one of the little flowers that you have removed. If you examine other little flowers in the head, you will find that they have parts similar to those of the little flowers that you have just examined. We see, therefore, that *the sunflower head is not one large flower, but is in reality a very dense cluster of tiny separate flowers.*

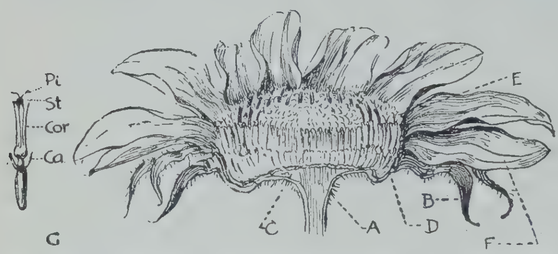


Fig. 208. Sunflower head cut lengthwise. A, Flattened end of the stem. B, Outer circle of protecting leaves. C, Buds. D, Flowers with stamens showing above the corolla. E, Flowers with forked pistils. F, Outermost flowers of the head with large yellow corollas. Do not mistake these for single petals. G, One little flower showing parts—*Ca*, calyx; *Cor*, corolla; *St*, stamens; *Pi*, pistil.

Now remove a little patch of the flowers from the head. Do you see that all the flowers in this head stand upon a platform that is formed by the flattened end of the stem?[1] Did you find this in either of the other plant families that you studied? You will remember that, in the mustards, each little flower stands upon a tiny stem of its own (Fig. 186).

[1]This flattened end of the stem is called the *receptacle.*

Fig. 209. Some common plants of the sunflower family. A, Cone flower. B, Wild sunflower. C, Field thistle. D, Canada thistle. E, Wild aster. F, Sow-thistle.

Turn the specimen around and look at the outside of the cluster. Do you see that it has surrounding it *several rows of green leaf-like parts* that protect it against injury? The flower clusters in other plant families have not this protecting wall around them.[1]

Preparation.—For the next lesson bring into the classroom flower heads of wild sunflower (Fig. 209, B), Canada thistle (Fig. 209, D), sow-thistle (Fig. 209, F), field thistle (Fig. 209, C), wild aster (Fig. 209, E), cone flower (Fig. 209, A), dandelion, purple blazing star (Fig. 210), gum-weed (Fig. 52), daisies, marigolds, cosmos, or any other plants that you can find that have flower heads.

Other flower heads.—Split the various flower heads lengthwise, and exchange them so that each member of the class may have several different kinds. Examine your specimens to find whether they are like the flower heads of the sunflower. In each case look for the answers to three questions: (1) Is the cluster made up of a *number of little separate flowers*? Take out a few from each head and find on each the seed-like fruit and the colored corolla. (2) Are all the flowers of each head *standing on the flattened end of the same stem*? (3) Is the cluster *surrounded by one or more rows of special protecting leaves*?

If you find that you have brought in some flower clusters that are not like the sunflower in these three ways, discard them. All the plants that, like the sunflower, have their flowers in clusters standing on the flattened end of the same stem and surrounded by one or more rows of protecting leaves are related to the sunflower. This large family of related plants is called the *Sunflower Family.* The sunflower family is the largest of all the plant families. Though we do not depend upon it as much as upon the grasses for food, it is nevertheless very important in other ways. Some of its members, such as the cultivated sunflower, the lettuce

[1]The protecting wall of special leaves around the flower head is called the *involucre.*

Courtesy W. C. McCalla.

Fig. 210. Blazing star.

plant, and the artichoke, are used as food for people and animals. Many of them we cultivate for ornament in our gardens, for example, chrysanthemums, dahlias, zinnias, cosmos, and marigolds; many others, like dandelions and thistles, unfortunately, are troublesome weeds. The sunflower family is the most widespread and the most successful of all the plant families.

Some of the autumn plants of the sunflower family are difficult to recognize as members of the family. The

Fig. 211. Golden-rod.

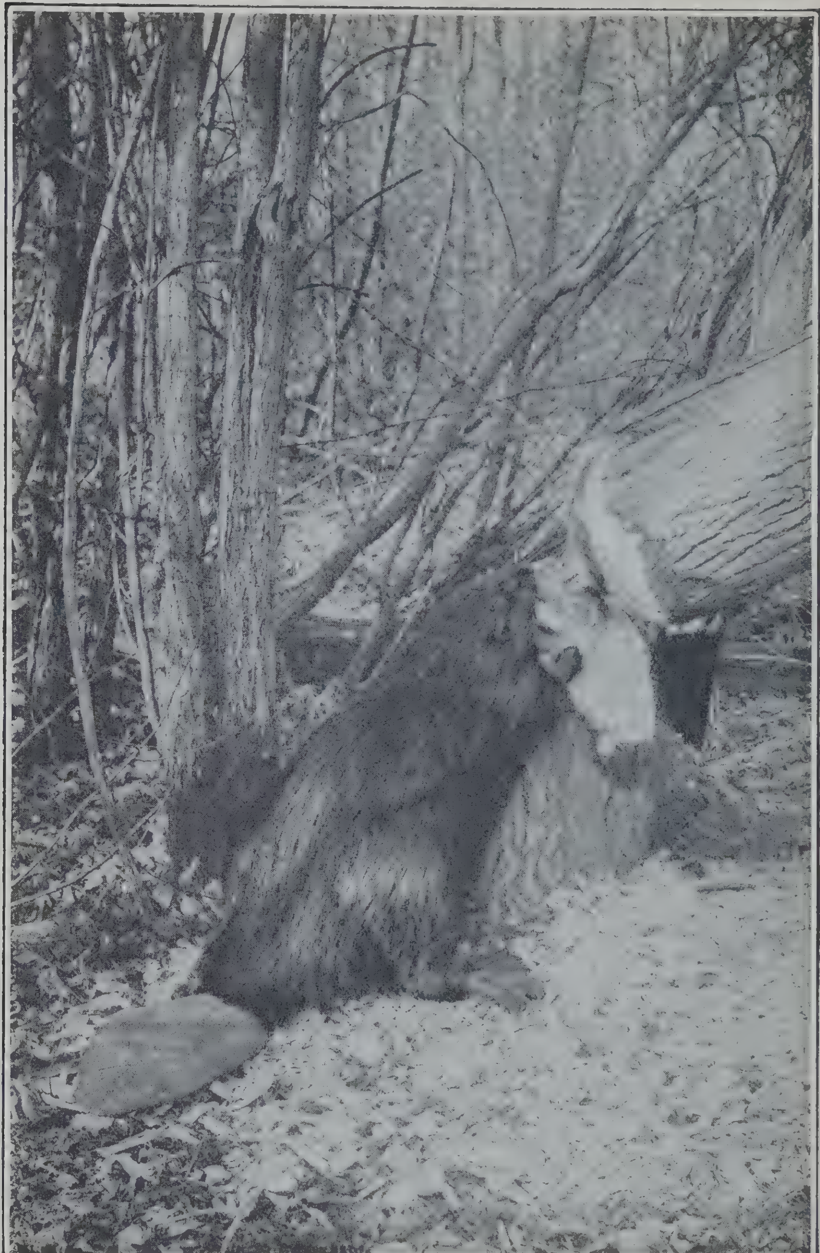
Fig. 212. Yarrow.

golden-rod (Fig. 211), wild aster (Fig. 209, E), and yarrow (Fig. 212), for example, have very small flower heads that are themselves arranged in dense clusters. In order to be sure that you can always recognize plants of the sunflower family when you find them, you have only to keep in mind what you found in the sunflower—the dense cluster of little separate flowers standing on the flattened end of the same stem, and the protecting circles of leaves around the whole cluster.

Note-book Record.—Make lists of the names of all of the plants that you have found in your district belonging to the mustard family, the grass family, and the sunflower family. At the head of each list state how you can recognize the plants of each family. Your lists of wild and cultivated plants may be illustrated by pictures cut from magazines or seed catalogues, by your own drawings or paintings, or by pressed and mounted plants.

Question Outline

(1) In what plant family have the flowers four petals and six stamens? (2) What plant family has hollow jointed stems and leaf sheaths? (3) In what plant family are there a number of flowers on the flattened end of one stem? (4) How is this kind of flower cluster protected? (5) How can you show someone that the head of a sunflower or thistle is not really one large flower? (6) Why would it not be correct to say that the circle of green protecting leaves around a sunflower head is the calyx? (7) The calyx of the little flowers in the sunflower head has almost disappeared, but in the thistle and the dandelion it has changed to fine bristles. Of what use is this tuft of bristles in these plants after the fruits are ripe? (See page 19.) (8) Which of the three plant families studied is the most important as a source of food for people and animals? (9) Which is the most widespread?



Courtesy Industrial Development Board of Manitoba.

Fig. 213. This beaver has just finished his work. Notice the pile of chips. What use do beavers make of the trees that they cut down? (See page 296.)

PART II

AUTUMN STUDIES OF ANIMAL LIFE

CHAPTER XXX

ANIMALS OF THE GREAT GRASSY PLAINS

In the chapter on the grass family we learned that grasses not only supply us with the wheat, corn, and other grains that we use for food, but also provide food for a great many animals. Because these animals live upon grass and other green food we call them *grazing animals.* Some of them, such as cattle, horses, and sheep, are familiar to us. We see them in the fields, or keep them about our homes. Others run wild. Of the wild animals, a few such as the deer, the moose, and the giraffe, that live partly upon the leaves and twigs of trees, are sometimes called *browsing animals.*

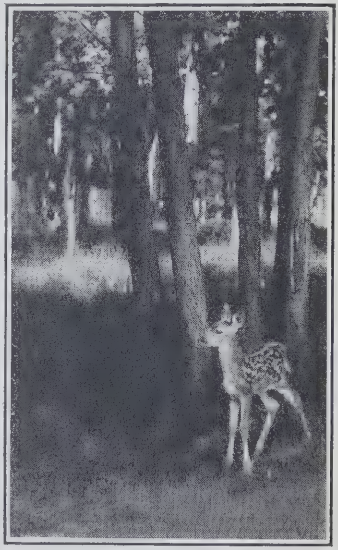


Photo by A. Burton Gresham.

Fig. 214. Fawn of jumping deer. This is one of the even-hoofed animals. Does it depend for its safety upon defence or escape?

Being grass eaters, the grazing animals live upon the grassy plains of the world (see page 259). Some, such as the zebra and wild horses, feed where the plain is high and dry and the ground is often baked hard and the grass is short. Others choose the low moist

plains that are often swampy and covered with low scrub. In these low places we sometimes find the buffalo or the

Fig. 215. Buffalo. These even-toed grazing animals once ran wild upon the moist fertile plains. How did they protect themselves against enemies?

deer (Figs. 214 and 215). On the high rocky plateau lands may be found such animals as the mountain goats (Fig. 216) and the antelope.

Fig. 216. Rocky Mountain goats. The two toes on each foot enable these animals to secure a firm footing upon the rocks. These goats are shedding their winter hair.

The feet of the grazing animals are especially suited to travelling over the plains on which they find their food. Their nails are developed into hard hoofs, which protect their feet. How many hoofs are there on the foot of a cow, horse, sheep, pig, deer? Collect the bones or hoofs of the feet of various domesticated grazing animals and add them to the school collection.[1]

[1]Small feet may be dried whole with skin and hair, by exposing them to the hot sun out-of-doors or to heat from a stove or radiator. There will be no odor from the flesh if they are injected freely with strong formalin by means of a hypodermic needle.

Animals like the horse and the donkey, which in the wild state lived upon the hard, dry plains, have a single hoof on each foot (Fig. 217). With this type of foot they could travel quickly and comfortably over the hard plains to find new pasture or escape from their enemies. The zebra, which runs wild over the plains of Africa, has a foot like that of the horse.

Fig. 217. Hind legs of a horse. Notice the position of the heel (H). The horse walks on the end of the toe and not flat-footed. Does this increase the length of the whole limb and enable the horse to travel quickly? Why would there be an advantage in having only one toe on each foot when travelling swiftly over the hard dry plain?

In contrast with these odd-toed or single-hoofed grazing animals are those with an even number of toes on each foot, well protected by hoofs (Fig. 218). Some of these, such as cattle, buffalo, and deer, make their homes in the moister parts of the plain, in low meadows and along the shores of streams. These animals, also, must run to escape their enemies and therefore need feet well protected by hoofs. For them, however, paired hoofs on each foot are better than one, because the two hoofs spread and prevent the animals from sinking in the softer ground of the lower plains as they flee from an enemy or travel from place to place. Even the very small pair of hoofs, at the back of each foot, is useful in bearing the weight of these animals when they are going through places where the turf or the ground is very soft. The camel, which is a grazing animal like the cattle, walks on two toes. These have only very small hoofs, but have broad pads of skin on them. The toes spread out and enable the animal to travel over the loose

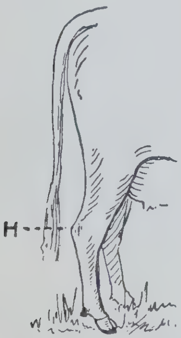
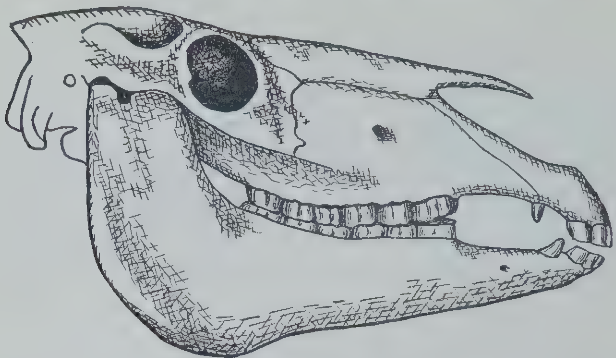


Fig. 218. Hind legs of a cow, an even-toed animal. What is the advantage of the two large hoofed toes on each foot? Has the foot any other toes? Notice the heel (H) on the foot. In what important way does the leg of a cow resemble that of a horse?

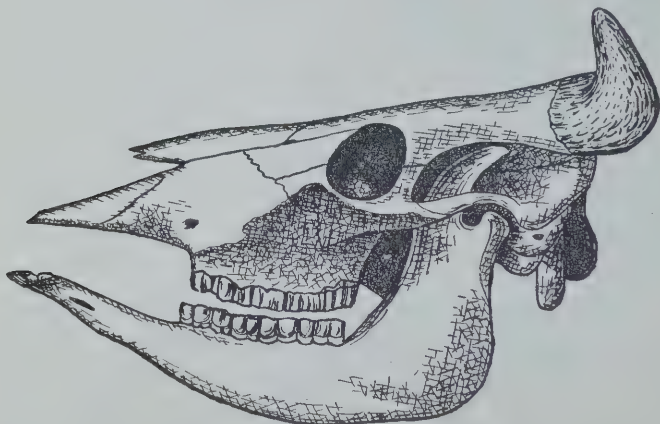
sands of the desert. Other even-hoofed animals, such as the mountain goats, find a safer feeding ground high up on



From "Zoology for High Schools," by Calvert and Cameron.
Fig. 219. Skull of horse. Notice the teeth in the front of the mouth by which the horse can bite off the grass that it eats.

rocky plateaus. The two pointed hoofs on each foot give them a sure footing as they jump from rock to rock.

Odd-hoofed animals like the wild horses and the zebras, that eat the short grass on the drier plains, have sharp-



From "Zoology for High Schools," by Calvert and Cameron.
Fig. 220. Skull of a cow. Are there any teeth in the front part of the upper jaw? How does a cow bite off the grass?

cutting front teeth on the upper and lower jaws that bite off the grass (Fig. 219). After biting off the grass, they grind

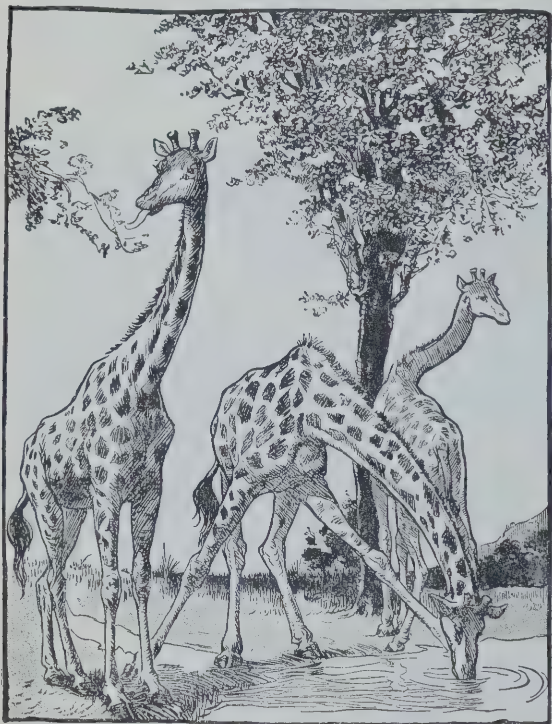
it with their back teeth before swallowing it. The domestic horse and donkey bite off grass and chew it before swallowing it in the same way as did their wild ancestors in the days when they wandered over the drier plains.

On the dry open plains grazing animals can see an enemy coming while it is still some distance away. They therefore feed in a leisurely way when they see no enemy about and

Fig. 221. Cattle chewing their cud while lying down in the shade. After feeding as rapidly as they could upon the long grass of the rich moist plains that were often partly covered with scrub, the ancestors of our cattle, no doubt, developed the habit of returning to a more open place where they could observe the approach of an enemy. There they would conceal themselves by lying down in the shade of a tree, and would grind up the food that they had swallowed without chewing.

chew their food as they eat it. On the lower plains, however, where the grass and other plants grow taller and the scrub is plentiful, the even-hoofed animals, like the deer, are in constant danger from enemies that may creep upon them unawares. In consequence, they have developed the habit of eating grass much more rapidly. This type of animal pulls the grass into the mouth by the tongue and cuts it off by pushing forward the lower teeth. Watch a cow biting off grass. Without chewing it, the cow swallows the grass

and then retires to a safer place where it can take time to chew the food properly. To do this it brings the food back from the stomach little by little and chews it with the grinding teeth found in the back part of the mouth (Fig. 220). Have you ever watched cows or sheep "chew the cud" in this way, as did their ancestors long ago (Fig. 221)?



Courtesy Thomas Nelson & Sons, Ltd.

Fig. 222. Giraffe. This browsing animal can reach the leaves of a tree more easily than it can reach the grass on the ground.

The giraffe, like the moose, has a foot with paired hoofs. It browses on the leaves and twigs of trees. With its long neck it can easily reach the leaves of trees but can reach the grass on the ground only with difficulty (Fig. 222).

How many hoofs are there on each foot of a pig? Does a pig eat grass? The wild pig, which dwells on wooded plains, eats a little grass but feeds largely on roots which it digs with its strong snout, and on nuts which it cracks with its numerous sharp teeth (Fig. 223). Like many grazing animals, it has on each foot two hoofs that carry its weight and two smaller hoofs. The hippopotamus (*hippos*, a horse, *potamos*, river), which belongs to the pig tribe, feeds on grass and other plants. Each foot

of the hippopotamus has four toes, each with a small hoof on it. Can you suggest an advantage to this animal in having so many toes on which to stand? The elephant (Fig. 224), which is also a very large animal, feeds on grass. It has five toes, each with a small hoof.

Fig. 223. Pig. This animal has two toes on each foot larger than the others. The toes are protected by hoofs. Why can the pig not run rapidly from an enemy? How did its ancestors protect themselves? What food did they eat besides grass?

Note-book Exercise.—Place in a list in your note-book the following names of animals that live on the grassy plains of the world: cattle, horses, pigs, sheep, camels, donkeys, mules, deer, elephants. Opposite each name write the uses made of each animal by mankind. Under this list make another list of four-footed animals that you know that do not live on grass. Put a mark opposite those that are very useful to people.

After Baker.

Fig. 224. African elephant. This grazing animal has five toes on each foot. Why is it not necessary for it to run from enemies?

Value of grazing animals to us.—When you have completed the note-book exercise, you will agree that the animals that live upon the grasses of the great plains of the world are the most important animals to man. We use them not only to supply us with food but to do work and to provide us with clothing and other useful things.

The horse and the donkey, natives of the dry grassy plains, have been domesticated and trained to work. It would be difficult to do without these animals that are so useful in tilling our land for crops (Fig. 225), in hauling heavy loads, and in taking people from place to place. Even when they are dead, these animals are valuable for their skins. What use is made of them?

Cattle, sheep, and pigs are useful to us in many ways. Apart from fish and fowl, most of the meat that we eat is obtained from these three kinds of grazing animals. From their hides we obtain a great deal of leather, from which we make shoes, harness, suitcases, and many other useful articles. Make a list of all the articles you know that are partly or altogether made of leather. At meal time we would not wish to be without the milk and butter that we get from cows. Thousands of pounds of cheese are made in Canada annually. From what is it made? In the cold winter we should miss the warm clothing made from the wool and skins of sheep. Without the many products obtained from our grazing animals our foods would be much less varied and healthful than they are, and we should lack many of the comforts and conveniences that we now enjoy.

Courtesy Dept. of Agriculture, Manitoba.

Fig. 225. Ploughing with horses. These grazing animals have been trained to do work for us.

Why grazing animals were domesticated.—Our ancestors of many centuries ago were not so fortunate as we are to-day. To obtain food and clothing they had to face the dangers of hunting wild animals, for they had not at that

time any domestic animals. They hunted those animals that ate grass. Why would it be less dangerous to hunt these than to hunt animals that eat flesh? They, no doubt, captured some of the young of these grass-eating animals and found that they were easily tamed. When these tame hoofed animals were fully grown, they were driven by their captors from pasture to pasture and from place to place, as they had previously been driven by the animals that preyed

Fig. 226. A small herd of cattle. Does their habit of herding together make them suitable for domestication?

upon them. Thus our ancestors provided themselves with a constant supply of meat, milk, and skins without exposing themselves to the risk of being killed by flesh-eating animals.

A wild animal is in greater danger of falling a prey to an enemy when it is young than when it is an adult, because when young it cannot run as swiftly as when it is fully grown. The shorter the time required for an animal to grow up, therefore, the less likely it is to be caught and killed. Those grazing animals that grew up most rapidly into adults in each generation no doubt survived, while the

Fig. 227. When kindly treated, cows become very quiet.

others were caught and destroyed by enemies. Our domesticated grazing animals are therefore descended from those animals that grew up quickly, and, although they are no longer preyed upon by other animals, they still retain this characteristic; they grow up in a very few years to full size.

Why are grazing animals suitable for domestication?—Because grazing animals, such as cattle and sheep, grow rapidly into adults, increasing greatly in size, they provide us with much food. The farmer finds that his stock soon grows and that he can exchange some of the increase for money. The more rapidly the animals grow and the more quickly products such as milk and meat can be obtained from them, the more rapidly the world's supply of food increases. These animals which grow rapidly are therefore especially suitable for purposes of domestication.

Courtesy Canadian Pacific Railway.

Fig. 228. Oxen are still used in pioneer districts for farm work.

In the wild state, grazing animals of the cattle tribe, when attacked by enemies, formed themselves into a herd. The stronger animals turned their heads outward and defended the weaker ones with their horns. Because these animals no doubt felt safer when they were in herds or flocks, it was not difficult to herd them together when captured (Fig. 226). As they were docile by nature, they soon became tame and learned to obey. To-day a child can milk a cow or drive a horse though these animals are much larger than a boy or girl (Fig. 227).

Though our domesticated animals thrive best when given shelter and food, most of them are very *hardy*. Horses and cattle can remain outside in winter on our cold plains. They sometimes even find food for themselves by pawing away the snow from the grass.

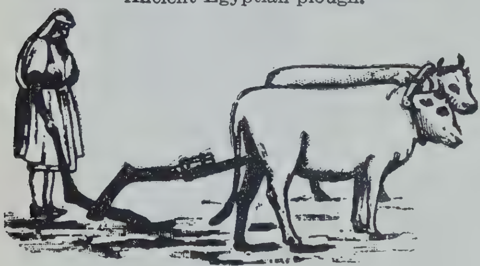
Fig. 229. The horse still provides a comfortable and rapid means of transportation, especially in places where good roads have not yet been made.

Horses, donkeys, and oxen are useful to us because they are strong and can be trained to work. For centuries horses and oxen have helped to till the land and pull heavy loads (Figs. 228, 230). In days gone by the horse was relied upon to carry people swiftly from place to place. To-day, however, we depend for transportation chiefly upon machines, though even yet where roads are poor the horse provides the swiftest means of travel (Fig. 229).

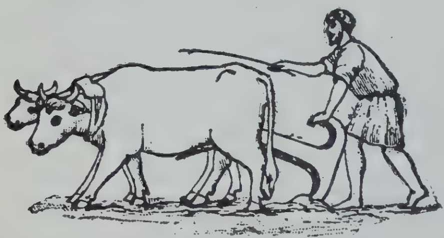
When our ancestors had captured and tamed animals to provide themselves with food, clothing, and a means of carrying burdens, they probably discovered that some of their animals were better than others. One cow would give

more or better milk than the others; one horse could run faster or carry a heavier load than the others; one sheep could produce longer or finer wool than the others. They therefore kept the best of these animals and killed only the poorer ones for food and clothing. When the calves, colts, and lambs of these best animals grew up, the best of these were again selected, and their young were kept. By selecting the best animals generation after generation farmers have so improved domestic animals that those of the present day are much larger, give more or better milk, and produce more or finer wool than did the animals of a few hundred years ago (Fig. 230).

Ancient Egyptian plough.



Persian plough.



Ancient Roman plough.

Courtesy Dept. of Agriculture, Manitoba.

Fig. 230. The animals used hundreds of years ago to till the land were not as large and strong as our domestic animals are to-day. How have they been so improved?

In selecting the animals to be raised size has not always been the only consideration. Some horses were selected because they were large and strong and could pull heavy loads, but others were selected because they could travel swiftly. In the Island of Jersey the people wanted cows that gave milk rich in cream. They therefore selected the

calves of the cows that gave the richest milk and kept these. By doing this generation after generation they developed the breed known as the Jersey cow, which gives milk very rich in cream (Fig. 231). Another breed of cows, the Holsteins, have developed in Holland because people there kept and raised only those cows that gave a large quantity of milk (Fig. 232). Similarly, various types of other domestic animals, such as sheep and pigs, have been selected. Thus breeders have not only increased the size of their domestic animals, but they have also developed, by selection, animals possessing various desirable qualities.

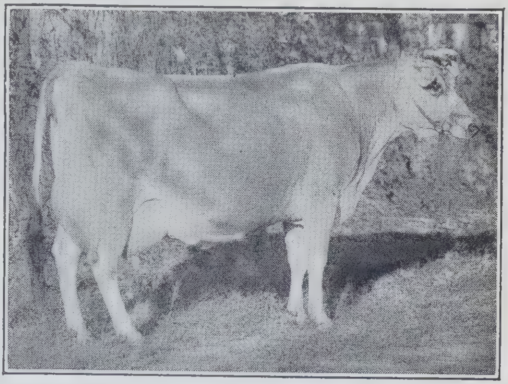


Fig. 231. Jersey cow. How has this type of cow been developed?

Courtesy Mount Victoria Farms, Quebec.

Fig. 232. Holstein cow. These cows have been selected for the large quantity of milk that they give.

How animals help us to turn grass into valuable products. — The horses and oxen that we have domesticated help us to do our work, and the cattle, sheep, and pigs supply us with milk, wool, meat, and skins. The food which enables these animals to work or to grow rapidly consists of hay and grain. This hay and grain is the grass and its seeds grown upon the great plains of the world.

The meat and milk that we use for food contain the same substances as the grass that these animals eat upon the plains, but these materials are changed within the animals' bodies into richer foods. The wool that we use to keep us warm is made from the grass eaten by the sheep. Thus we see that, by domesticating animals, people have been able to use them to change some of the grass of the plains into rich food, warm clothing, and other valuable products.

Question Outline

(1) On a sheet in your note-book make three vertical columns. Head the first column "Grazing Animals, Domesticated and Wild, that are Even-toed". Head the second column "Grazing Animals, Domesticated and Wild, that are Odd-toed". In the third column place the heading, "Five-hoofed Grazing Animals". In each column write the names of the animals that belong in that particular class. (2) What are browsing animals? Give two or three examples. (3) How many hoofs are found on each foot of grazing animals native to the dry open plains? (4) Why is this kind of foot suited to this region? (5) Do animals of these drier plains chew the cud? (6) Have they teeth on the upper as well as on the lower jaw to bite off the grass? (7) To what region of the plains are the even-toed grazing animals native? (8) What aids them in travelling over the soft, moist plain or in jumping from rock to rock? (9) Do they eat their food rapidly? Why? (10) When do they chew it? (11) Compare the front teeth of a cow with those of a horse. Explain the advantage to these animals of the different ways in which they bite off and chew their food. (12) Why are animals that feed on the great grass plains valuable to us? (13) Explain what is meant by saying that nearly all of our food and all of our woollen clothing come from grasses. (14) Give reasons why grazing animals are especially suitable for domestication. (15) What changes has man brought about in these animals? How?

CHAPTER XXXI

RODENTS OR GNAWING ANIMALS

Introduction.—We have seen that some of the larger animals of the great plains have been tamed and domesticated by people living upon the plains. These grass-eating (grazing) animals have become very valuable servants of man, helping to do his work and to provide him with food. But there are other groups of animals which are not so useful and some which are actually enemies of man. The small six-footed animals (insects) that we have already studied belong in one of these groups. We shall now consider representatives of another harmful group — certain warm-blooded, fur-covered animals that feed upon grasses, the bark of trees, and other plant foods.

The best way to learn about animals of this group is to observe them in their homes as you observe birds, or to keep several of them in a cage where, by caring for them, you may make friends with them and thus have an opportunity to watch their actions.

If you make careful preparation for keeping animals in cages, you may have a very interesting time with them and may learn from them the answers to many questions that you might wish to ask. To make a success of keeping animals as pets you must provide for them: (1) a regular supply of clean water, (2) suitable food, and (3) a clean, comfortable home. If these three needs are not provided for, the animals will be unhappy and will not show you how they live in their natural surroundings.

Various kinds of cages may be purchased from dealers, and many simple kinds may be made at small cost. For very small animals, wire

screen cages like those used for insects (see Appendix, Sec. 3) may be used, but for larger animals more substantial cages are required. Two satisfactory types are suggested in the Appendix (Sections 16, 17, and 18). The cage should be ready before the animal is procured.

Any wild animal will be frightened when first caught and put in a cage. A shelter should therefore be provided in which the animal may hide. This shelter may be a small box within the cage, straw or hay in which the animal may make a nest, or even dry turf in which it may burrow. After being placed in the cage, the animal should be left alone until it comes out of its hiding place to look around. When it comes out, whether by day or by night, it should find food and water ready for it. If it is not tormented, it will soon learn that it is not in great danger, and will then become tame. After it is tame, keep it only as long as you are willing to give it food, water, and a clean bed regularly. Most of the gnawing animals can be kept healthy, if, in addition to being given plenty of clean water, they are fed upon raw turnip, carrots, potatoes, lettuce, or other fresh vegetables, and a little bread or grains. They are fond of the green sprouts of wheat, oats, or barley that have grown to a height of two or three inches. Some animals like to have a piece of grassy turf in one end of the cage. No gnawing animal (even a mouse or a rat) should ever be given meat or cheese.[1]

Questions to ask a living animal.—Let us suppose that you have secured one of the gnawing animals that we shall study in this chapter, for example a rabbit, a squirrel, a guinea pig, a gopher, a field mouse, a rat (white or wild), a muskrat, or a porcupine (Fig. 233). What questions

[1]For full information upon the keeping of pets refer to *The Pet Book* by Anna B. Comstock, Slingerland-Comstock Co., Ithaca, N.Y. This is a wonderfully interesting book and tells how to look after many kinds of pets, from ponies to waltzing mice, from canaries to peacocks, as well as fishes, frogs, turtles, crayfishes, and many other kinds. It has also interesting stories and pictures of pets and their owners. It should be in every school library.

should you try to answer from watching it? Since the first need of the animal is food, you can soon learn much about its various kinds of food and how it eats them. Watch its mouth and notice its teeth while the animal is eating. The rabbit (Fig. 234) has a peculiar upper lip that enables it to gnaw without hurting the lip, and other animals have peculiarities of other kinds. Notice whether the animal uses its front feet for holding objects, whether it stands upright on its hind feet, whether it has a "thumb," and whether its claws are suited to clinging to trees or to digging in the ground (Fig. 235). Observe its eyes. Can it see behind it? Notice its ears, its fur coat, and its ways of making itself comfortable when it is resting. Does its color protect it when asleep? These and many other questions you can answer by watching the animal.

Fig. 233. Porcupine. Does this rodent depend for safety upon escape or defence?

Fig. 234. Rabbit in "scouting" position. Compare this with the position shown in the frontispiece.

One of the most interesting ways of keeping a record of what you discover is to set apart a page or two in your note-book for animal observations. In this space write down from time to time anything that you observe about your guest that you think will be interesting to read later.

Does it not surprise you to observe that this little animal is able to look after itself in every way much better than you could look after yourself at its age? Even though it has no hands, no tools and no dishes to use, no books and no school in which to learn about the world, and no doctors to help it in sickness, and at the same time is surrounded by many enemies that seek to destroy it, yet it thrives. Do you think that such animals have much time for play? Are they often frightened by enemies? Are they frequently injured or sick? Do they suffer much from hunger or cold? Doubtless many of them do suffer in various ways, but probably the best workers among them usually succeed best, while the idlers soon provide tasty meals for watchful enemies.

Fig. 235. Squirrel. Notice the use of the front feet for holding the nut. Has it strong front teeth?

Homes and foods of rodents.—While observing the specimen in its cage, let us consider a few questions about its natural home and about the homes of other rodents. You cannot study all of them closely, but you should try to make friends with at least one family of rodents living out-of-doors. Squirrels and chipmunks (Fig. 236) make particularly interesting out-door pets, and, if they are fed, they will become very tame.

Fig. 236. Chipmunk. This rodent eats berries, seeds, and insects as well as nuts.

Even a family of gophers may be tamed to some extent by feeding, especially if they live in a place where food is scarce.

Which of the gnawing animals that you have seen make their homes in trees? Do any of them live only on the ground? Which of them make homes by burrowing under the ground? Have any of them taken to living in water, or close to the water's edge? Can you think of any advantage that they gain by living in such places? Make a list of the rodents that you know, showing where they live and what they eat. If you are in doubt about any of them, refer to the summary of homes and foods of rodents given on page 304.

Teeth of gnawing animals.—You may have seen the strong, sharp cutting teeth at the front of the mouth in your living specimen, and you may have seen also how it uses them in eating. If you place in the cage a small branch from a young poplar tree, you may see the animal nibble at the bark. Bark is an important source of food for rabbits in winter when the snow is deep. Have you seen small poplar stems peeled by rabbits? To understand how very important these strong, sharp teeth are to gnawing animals, and how they differ from our own teeth and those of other animals, we must look at a skull in which we can see a complete set of teeth.

Preparation.—Prepare or procure from the school collection one or more mounted skulls of gnawing animals. These should be examined closely so that each member of the class may see the points described below. The preparation and mounting of skulls is explained in the Appendix (Sections 21 and 22).

Examine carefully one of the skulls and compare the teeth of the animal with your own. Notice that it has at the front an upper and a lower pair of long curved teeth with sharp chisel edges. These are the teeth with which the animal gnaws wood. Why do they not become dull with cutting

such hard material? If you examine them closely, you will see that the inner side of each tooth is worn down, leaving a sharp outer edge. This explains how these teeth are kept constantly sharp. With them the animal can cut twigs from bushes or bite through the bark of trees. With his gnawing teeth the beaver (Fig. 213) can cut completely through a fairly large tree, biting out chips almost as large as those that a woodman makes with an axe. With these teeth also, mice and rats are able to gnaw their way into buildings and to do great damage. The gnawing teeth of these animals are not only sharp and strong, but, as they wear away, they constantly grow so that they do not become short. All the animals that have growing front teeth which enable them to gnaw wood are probably related to one another. We say, not that they are all of the same family, but that they all belong to a great tribe or "order" that we call the **Rodents,** or Gnawing Animals.

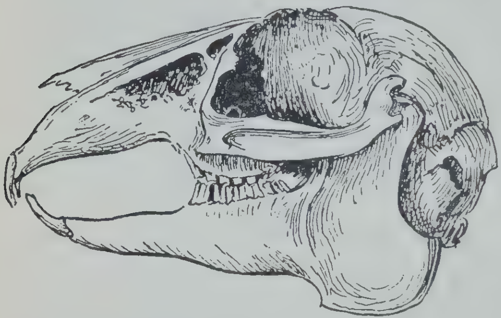


Fig. 237. Skull of rabbit. Notice the growing front teeth, the strong grinders, and the space. What is the use of each of these?

In the skull of a rabbit (Fig. 237), notice that there is an extra pair of very small teeth directly behind the upper pair of front gnawing teeth. These may help in cutting off thin grass stalks or in preventing the lower teeth from cutting the roof of the mouth.

Several other points can readily be noticed about the teeth and jaws of rodents. On your specimen you will see that there is a wide gap between the front teeth and the back teeth. Is there such a gap between your own front and back teeth? The skin of the cheeks of the rodent may

be drawn inward across the mouth opening, through this gap in the teeth, so that, when the animal is gnawing wood, it need not take the chips into its mouth unless it wishes to do so. In our mouths and in the mouths of many other animals, in place of these gaps there are very strong sharp teeth. Have you seen these long, strong teeth in a dog or a cat? For what purpose are they used?

Fig. 238. Field mice. These rodents are often very numerous under the sheaves in the fields in autumn.

The back teeth of the rodent are very strong, and have large rough surfaces suited to grinding up woody food. Notice in the mounted skull that the lower jaw is narrower than the upper so that the teeth do not meet evenly. Do these animals chew with an up-and-down movement of the jaw or with a sideways movement? The jawbones are very thin, but are very broad at the base. To their broad surfaces very strong muscles are attached that pull the jaws together powerfully, enabling the front teeth to cut through wood, and enabling the back teeth to grind up bark for food. Can you see the hinge of the jaws?

Fig. 239. Rat. This is the most harmful warm-blooded animal.

Find the eye socket, the openings into the inner ear, and the box of bone at the back of the skull that protects the brain. These parts are shown in your specimen and also in the diagram of a rabbit skull (Fig. 237).

Courtesy U.S. Public Health Service.
Fig. 240. Rat guards on the mooring hawsers of a ship.

Harmful rodents.—Among the larger animals, including birds, we found that we have many friends, and only a few enemies. In the case of insects we found that the reverse of this is true—that in this group we have many enemies and only a few friends. Let us now see whether we have more friends or more enemies amongst the rodents.

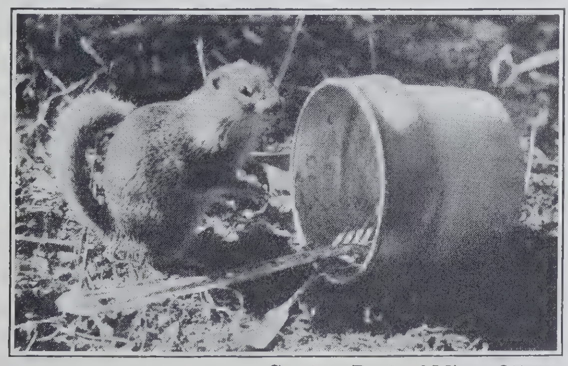
Let us first consider some of the harmful rodents and the ways in which they do harm. A number of the harmful rodents you already know quite well. The house mouse, for example, though he is an interesting animal to keep in a cage, must be classed as harmful because mice do a great deal of damage in houses, stores, and other places where food or clothing is stored. The field mouse (Fig. 238) is another harmful rodent. In some years field mice cause enormous losses by damaging unthreshed crops.

Courtesy Dept. of Interior, Ottawa.
Fig. 241. Flickertail gopher. This is the common brown gopher of the grain fields.

You can, without hesitation, class rats (Fig. 239) among the harmful animals, and you can probably tell, from observation, about the harm that they do. The common brown rat carries many kinds of diseases, the most deadly of which is the bubonic plague, known in history as the "black death." In the numerous epidemics of this disease through the centuries, it has caused more deaths than all the wars that have been fought. In India in the year 1907 alone the plague killed nearly two million people. In Canada outbreaks of rat-carried diseases are rare, but damage done by rats in other ways is very serious. A rat eats about forty-five pounds of food per year, and in obtaining this it often destroys other food and damages the building in which it is stored. On the farm rats destroy chickens and nesting birds and sometimes even young pigs. In the city they destroy foods, furniture, and other goods. They may start fires by gnawing matches or the insulation

Courtesy Dept. of Interior, Ottawa.

Fig. 242. Striped gopher. This gopher usually lives in grass fields or along roadsides.



Courtesy Dept. of Mines, Ottawa.

Fig. 243. Scrub gopher. This gopher does much damage to birds.

of electric wires. They do great damage on ships and are carried by them to every country in the world (Fig. 240).

The damage done by rats in Canada probably equals a tax of between one and two dollars a year for each person in the country. We should therefore make every effort to lessen the number of rats and to decrease the amount of harm that can be done by those that remain.[1]

Of the other harmful rodents the most familiar about the grain fields are the gophers (Figs. 241, 242, 243, and 244). They destroy much growing grain in the summer and store enough to last them all winter. The gopher competition conducted each year by the provincial Department of Agriculture is an important means of reducing the damage done by gophers. If gophers are numerous in your district, find out about the competition and enter it.[2] Squirrels, if they are numerous, are harmful on account of their habit of robbing birds' nests. Rabbits often do harm by gnawing the bark off fruit trees (Fig. 330) or by biting off the young twigs.[3]

After Bailey.

Fig. 244. Pocket gopher. This gopher has very large cheek pouches that open outside the mouth. Notice the smooth tail.

Useful rodents.—Among the gnawing animals there are a few that are very valuable to us. These are rodents that

[1]Cats are of very little use in destroying rats, and they destroy many useful birds. For a description of the best methods of destroying rats and of rat-proofing buildings write to the Publications Branch, Department of Agriculture, Ottawa, for the latest bulletins on this subject, also to the Superintendent of Documents, Washington, D.C. for the following bulletins: No. 33 (*The Brown Rat*), No. 369 (*How to Destroy Rats*), and No. 896 (*House Rats and Mice*). (Price about 15 cents each.)

[2]For notes on the different kinds of gophers see the table on page 304.

[3]Write to the Publications Branch, Department of Agriculture, Winnipeg, for the latest bulletins on harmful rodents.

live much of their time in water, and require thick waterproof fur to keep their bodies dry and warm. The muskrat (Fig. 245) and the beaver (Fig. 213) are the two most important fur-bearing rodents. Their fur has a soft, fine inner layer and an outer covering of long, coarse "guard hairs." The guard hairs keep the inner coat straight and help to carry off the water when the animal comes out on land. As their

Courtesy "Fur Trade Journal of Canada."

Fig. 245. The muskrat at home. Notice the stiff guard hairs among its soft fur. Its house of grass and rushes is shown at the left.

skins and fur are very warm and wear well, they make excellent clothing.

The muskrat is now the most important fur-bearing animal of the central region of Canada, greatly exceeding in value the beaver which was once so plentiful. The fur is "plucked" (that is, the water hairs are removed) and then dyed to make "Hudson seal." It is sold under this name as well as in the unplucked and undyed condition. Beaver fur also is used for coats in both the plucked and the un-

plucked condition. Learn to distinguish the different kinds of furs that you see.

A few other rodents are of some use to us. Rabbits, for example, are eaten as food, and both rabbits and squirrels are used to a slight extent for fur. Such animals as guinea pigs and white rats, that thrive in small cages, are frequently kept as pets. They are also of great service to scientists, who use them in experimenting to discover the causes of disease and the means of preventing it. In these ways animals have done much to improve man's health and increase his comfort.

Rapid increase of rodents.—Though the rodents are all small, some of them are very harmful, and others are very useful. Why are these small animals so important? Because they are so numerous. One field mouse or even a hundred field mice would make very little impression on a crop of grain, but many thousands of mice may eat a large part of the crop. Similarly, a few rats, gophers, squirrels, or rabbits do very little harm, but, whenever they have plenty of food and are protected from their enemies, they increase rapidly in numbers, so that there are soon enormous numbers to be fed. Because of their rapid increase, rodents may do great damage to property.

It is difficult to realize how rapidly the numbers of such animals may increase where food is abundant and other conditions are favorable. Let us suppose that one pair of rats found a home in a stack of grain or in a warehouse where they found plenty of food and warmth but no enemies, disease germs, or other causes of harm. This one pair of rats might raise ten young rats every two months, and the young might again raise ten more after they were grown up at three months of age. At this rate you can readily calculate that at the end of three months there would be 22 rats, at six months 182, at nine months 1352, and at the

end of a year 9612. If each pair of these produced this number, what would the total be at the end of a second year?

These numbers would be correct only if none was killed. Fortunately, however, in our climate the increase of rats is slowed down in winter, and everywhere enemies are helping to keep them in check. The figures serve to show, however, that rats, mice, and other harmful rodents are all able to increase very rapidly. It is this ability to increase rapidly that enables them to do so much harm about our homes and other buildings.

The useful fur-bearing rodents, such as the muskrat and the beaver, are able to increase rapidly also. This makes up for the fact that their skins are small and that a considerable number of them are required to make one coat. A pair of muskrats raise about ten young per year. A small colony, therefore, may soon become large if the season is favorable. Millions of skins are taken each year, but in those districts where they are taken at the right season the muskrats seem to be as plentiful as ever. In years when disease or lack of water makes increase slow, only a few should be taken for skins. The habit of increasing rapidly, which enables most rodents to do so much harm, makes fur-bearing rodents very valuable.

Question Outline

(1) Which are more useful to people, grazing animals or gnawing animals? (2) Write a short account of an animal that you have kept in a cage so that someone else might learn how to look after the same kind of animal. (3) In what different kinds of homes do rodents live? (4) Describe the teeth of a rodent. (5) How are the gnawing teeth kept sharp? (6) Why does a rodent require strong grinding teeth? (7) What is the advantage of the wide gap between the front and the back teeth of rodents? (8) What is the advantage to a rabbit of having its eyes on the sides of its head? (9) What harm is done by rats? What other rodents are harmful? (10) What rodents have you found in your district? (11) What rodents are useful? (12) Why is their fur good for clothing? (13) Why are the small rodents able to do so much more harm than large animals?

SUMMARY OF THE HOMES AND FOOD OF RODENTS

(This table is to help you to observe the rodents out-of-doors.)

Name	*Kinds*	*Home*	*Foods*
Rabbits	(*a*) Bush rabbit or varying hare	Wooded land	Herbs in summer, bark in winter.
	(*b*) Jack rabbit or prairie hare	Open prairie and small scrub	Herbs, bark, and grains.
Gophers	(*a*) Striped gopher (13 stripes)	In burrows on open grassy plains or roadsides.	Grasses, grains, eggs and young birds; seeds stored over winter.
	(*b*) Common brown gopher (flicker-tail)	In burrows on open plains, particularly in grain fields	Similar to the above but more grain destroyed.
	(*c*) Pocket gopher	Burrows under mounds like "mole hills"	Grain and other plant food.
	(*d*) Scrub gopher or gray "ground squirrel"	Borders of scrub	Young birds, insects, grain.
Squirrels	(*a*) Gray ground squirrel	(This is the scrub gopher.)	Same as scrub gopher.
	(*b*) Red squirrel	Woods	Nuts, berries, fungi, eggs, young birds.
Chipmunk or "rock squirrel"	(*a*) Eastern chipmunk (*b*) Western chipmunk	Borders of woods, in parks and other open woods.	Berries, seeds, nuts, mushrooms, insects, eggs, young birds.
Rats	Brown	About buildings, grain stacks, etc.	Plant materials, chickens, any human food.
Mice	(*a*) House mouse	About buildings (nests made in clothing, papers, etc.)	Any human food.
	(*b*) Field mouse	Cultivated fields under sheaves, stacks, etc.	Grains, alfalfa, seeds, bark of young trees, berries, vegetables.

CHAPTER XXXII

CARNIVOROUS ENEMIES OF RODENTS

Introduction.—As we have seen, the rapid increase in the numbers of rats, mice, gophers, and other harmful rodents often results in great loss, particularly to farmers and gardeners, fruit growers, and merchants whose goods are stored in warehouses. Indirectly we all suffer loss through these animals because the waste that they cause increases the prices of things that we buy. If the increase of rodents were not checked, these little animals would soon become so numerous that they would devour nearly all of our crops, trees, gardens, and stores of goods. Why does this not happen?

What checks the increase of rodents?—To answer this question recall what you know of the enemies of rodents. Do any birds live upon rodents? Are rodents eaten by other animals? Doubtless we have to thank coyotes, foxes, and badgers, as well as the birds of prey that live upon rodents, for preventing them from over-running our fields and homes. Animals that feed thus upon flesh are called *carnivorous animals* (*carnis*, flesh, *voro*, devour). Without the protection of these carnivorous animals we should be literally "eaten out of house and home" by rodents.

In any region where rodents become *very* numerous they are usually attacked by another enemy—disease. When they are living crowded together, it is very easy for disease germs to spread among them. You have probably heard it said that rabbits are killed off about every seven years by disease. This means that each time they become very

numerous, the disease spreads more easily and kills them in great numbers. Disease does not check the increase of rodents greatly, however, until they have become very numerous. We must therefore depend for our protection chiefly upon birds and other animals.

Rabbits and coyotes.—If the rabbits in a certain district find food very plentiful, they will increase rapidly in numbers.

Courtesy Dept. of Mines, Ottawa.

Fig. 246. Coyotes keep down rodents but do some harm when too numerous.

This will make more food for the coyotes of the district, and they, too, will multiply rapidly (Fig. 246). As the coyotes become more numerous, they will eat more and more rabbits, until the number of rabbits begins to decrease. Food will then become scarce for the coyotes, and they will stop increasing. Many of them will leave the district or will die of starvation. In this way the numbers of rabbits and coyotes in the district will be kept balanced. This is an example of the "Balance of Nature."

From "Life Histories of Northern Animals" by Ernest Thomson Seton, by courtesy of Doubleday, Page & Co.

Fig. 247. Fox and rabbit. Why did the rabbit let the fox come so close before darting away?

If all the coyotes and foxes in a district were killed by hunters, what difference would it make to the increase of rabbits and other rodents such as gophers and field mice (Fig. 247)? The rodents would probably increase greatly and do more harm than was done by the coyotes and foxes. Although coyotes, when they are too numerous, occasionally steal chickens or even sheep, they also do much good. If they become so numerous that they must come to the barnyard to find food, it is perhaps a sign that their numbers should be decreased a little; but so long as there are enough rodents to supply them with food, coyotes should be left alone to carry on their work of destruction and thus prevent the rodents from increasing in numbers.

Courtesy Dept. of Mines, Ottawa.
Fig. 248. Lynx, a carnivorous animal of the cat tribe.

We should think carefully what the results will be before we kill off coyotes, foxes, badgers, or other carnivorous animals or birds of prey. Experience has proved that it is never wise to upset the balance of nature by killing off *all* the animals of any one kind. We should make use of this means provided by nature to protect ourselves against rodents, and be very careful never to kill so many of any kind of carnivorous animal that the rodents of the district will not be held in check.

Other animals that live upon rodents.—Do carnivorous animals destroy many rodents? A coyote requires as much

food as a small dog, and, to find it, spends its time hunting over the plains and in the woods. Its food is largely field mice and rabbits with some gophers and other small animals. In winter it is limited chiefly to rabbits and mice. If it catches only one rabbit every other day, or half a dozen mice each day, how many would it take during the winter? This destruction will do much to prevent the rodents from becoming a plague during the next summer. Many other important fur-bearing animals, such as foxes, wolves, wolverines, lynx, marten, weasels, and mink, also depend largely upon rabbits and mice for food (Figs. 248, 249, and 250). They are therefore valuable not only for their furs but for the good that they do in destroying harmful rodents.

Fig. 249. The weasel is the enemy of rodents and of birds.

Birds of prey.—The carnivorous animals that we have named are not the only animals that feed upon rodents. Many kinds of birds also eat rodents and help to keep them in check. Such carnivorous birds are usually spoken of as "birds of prey."

Courtesy "Fur Trade Journal of Canada."
Fig. 250. The mink is one of our commonest fur-bearing animals. It lives chiefly upon fish, muskrats, and rabbits. Is it harmful as well as useful?

Courtesy American Museum of Natural History.
Fig. 251. Hawk with mouse. Nearly all hawks do much more good than harm.

Have you seen a hawk soaring over a field, searching for mice or gophers, or for an occasional rabbit? Because hawks sometimes do considerable damage in the barnyard, many people have the idea that all hawks are harmful and should be killed. This is a serious mistake, since no one can tell whether a bird or other animal should be destroyed as harmful until a thorough study has been made of the good and the harm that it does. Scientists have made a thorough study of hawks and owls and have found that, out of seventy-three kinds (nearly all in Canada), only six kinds do more harm than good. Of these six, only two are common in the well-settled districts of Western Canada. There are, therefore, only two kinds of hawks in Western Canada that should be killed whether they are visiting the barnyard or not. These are the sharp-shinned hawk and the Cooper's hawk. Look them up in *Birds of Western Canada*, and read what is said there about the various kinds of hawks and owls.

Courtesy "Nature Magazine.
Fig. 252. Owls kill great numbers of mice.

Hawks and owls pay many times over for all the chickens that they take. Some of them kill small birds at certain seasons, but their constant war upon harmful rodents pays for these also. In any locality a few hawks may come to the barnyard and do more than their share of harm. If these cannot be frightened away, it may be necessary to kill them, but other hawks should not be killed off because of the bad habits of one or two.

The small owls live upon insects, and the largest varieties

Courtesy U.S. Biological Survey.

Fig. 253. Skulls of field mice and three of the pellets of hair and bones which owls disgorge after digesting their prey.

take rabbits, but most of the owls feed upon mice. They seldom do much harm. They should therefore be protected unless they are actually seen taking chickens (Fig. 252).

We have seen that there is a natural balance between the rodents and the carnivorous birds and animals that prey upon them. As people move into a new district, this balance is sometimes upset by driving from the district certain kinds of birds or animals. This may result in other kinds becoming so numerous that they do more harm than good. We have also seen that, though it may be necessary occasion-

ally to kill off some carnivorous birds or animals, they should in nearly every case be protected so that they may prevent too great an increase of harmful rodents (Fig. 253). We should never kill them off without first finding out what harm and what good they do.

Question Outline

(1) What kind of harm do the carnivorous animals prevent? (2) Has the number of rabbits any effect upon the number of coyotes in a district? (3) What effect has the number of coyotes upon the number of rabbits and field mice? (4) Are coyotes of any use in a neighborhood? (5) How can we decide whether any kind of animal should be killed off or not? (6) Of what use are the rodents in the far northern woods? (7) Upon what kind of animals do the birds of prey chiefly live? (8) Should we kill hawks and owls whenever we see them? (9) What kinds of hawks have been found to do more harm than good? (10) Is it wise to kill any of the others if they keep out of the farmyard? (11) Should any kind of animal be killed off completely?

PART III

STUDY OF AIR

CHAPTER XXXIII

AIR

Our need of air.—What is the longest period during which you have gone without food? Some men have lived for nearly a month without food and have existed for several days without water. Can we live without air for similar periods? If you have ever tried "to hold your breath," you know that you cannot be comfortable long without air. We may live without food for nearly a month and without water for several days, but, if we could not obtain air, we should be dead in a few minutes. Fortunately, we find air to breathe everywhere upon the surface of the earth.

Have you ever seen air?—Air is invisible. Because of this, little has been known about it until recent times. In earlier days, men knew that air, when it moved, would turn their windmills and drive their ships, but they could tell very little more about it.

Is air matter?—If you hold a piece of wood in your hand, you cannot put anything else in exactly the same place because the piece of wood takes up room, or *occupies space.* By picking it up or by putting it on scales you learn that it *has weight.* If you press it between your thumb and fingers, you cannot bring your thumb and fingers together because the piece of wood *offers resistance.* Anything that occupies space, has weight, or offers resistance is called **matter.**

Unlike wood, air is invisible. It is therefore difficult to experiment with it. Moreover it surrounds us on all sides so that when we use up part of the air, more air rushes in to take its place, just as water rushes into the space that is left when we dip a pail of water from a pond. When experimenting with air, it will therefore be necessary to enclose the portion that we wish to use.

PROBLEM I. DOES AIR OCCUPY SPACE?

Experiment I

Object.—To find out whether air occupies space.

Apparatus.—A large dish of water, a quart jar or large beaker, a flat piece of cork (Fig. 254).

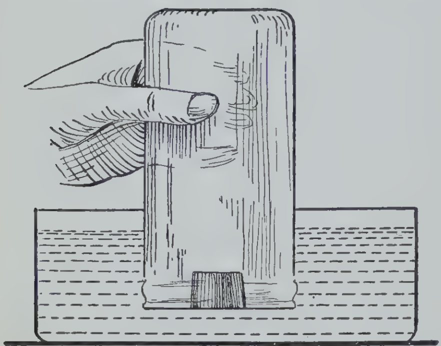


Fig. 254. What prevents the water from rising further in the jar?

Method.—Place the piece of cork on water in the dish. Invert the jar (or large beaker) over the cork floating on the water and force the jar downward into the water.

Observation. — Does the cork rise in the jar to any extent?

Conclusions. — (1) Does air occupy the enclosed space within the jar and prevent the entrance of water? (2) Does air occupy space or room? (3) Is air *matter*?

Experiment II

Object.—To find out whether air occupies space.

Apparatus.—A bottle, a thistle-tube, a rubber stopper to fit the bottle (the stopper should have a hole in it large enough to admit the thistle-tube), water in a beaker.

Method A.—Put a little water in the bottom of the bottle. Insert the thistle-tube in the stopper and put the stopper tightly into the bottle (Fig. 255). Make sure that the bottom of the thistle-tube goes down into the water. Then pour a little water into the thistle-tube.

Observations.—(1) Can you pour water through the thistle-tube into the bottle? (2) Is the space within the bottle filled with air? Is there any way in which it can escape to let water enter and take its place?

Conclusions.—(1) Does air occupy space? (2) Is air matter?

Method B.—Now draw the thistle-tube up through the stopper so that the lower end of it is well above the level of the water in the bottle. Again pour water into the thistle-tube (Fig. 256). Tap on the side of the bottle if the water does not begin to run.

Observations.—(1) Does any water enter the bottle now? (2) Does it flow steadily or in gushes? (3) What is disturbing the water as it runs down the thistle-tube?

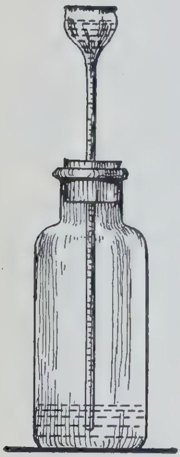


Fig. 255. Why can the water that is in the thistle-tube not run down into the bottle?

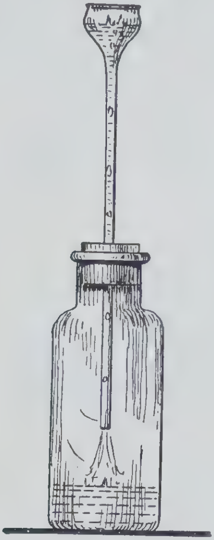


Fig. 256. Why does the water enter in spurts? (A thistle-tube with large bore shows this best.)

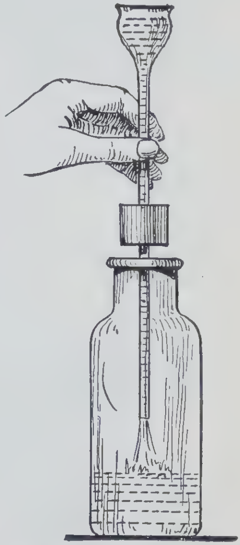


Fig. 257. Why can the water run into the bottle in a steady stream when the stopper is loose?

Conclusions.—(1) What is being pushed out of the bottle, allowing the water to enter? (2) Why cannot the water flow in steadily? (3) Does air occupy space or room?

Note.—Have you ever wondered what causes the water to escape in spurts when you turn a bottle of water upside down? Explain.

Method C.—Loosen the stopper, raise it just above the mouth of the bottle, and pour more water into the thistle-tube (Fig. 257).

Observations.—(1) Does the water run into the bottle? (2) Can air easily escape from the bottle now when water enters it? (3) Is there any spurting as the water runs through the thistle-tube? Why?

Conclusions.—(1) What is pushed out of the bottle as the water enters? (2) Does air occupy space? (3) Is air matter?

NOTE.—When you pour tea into an "empty" cup, does anything pour out of the cup as the tea enters? When you enter a room, what leaves it?

Experiment III

Object.—To find out whether air occupies space.

Apparatus.—A bottle, a flat glass cover for it, water in a flat dish, a piece of glass tubing bent at one end.

Method.—Fill the bottle with water and place the glass cover over its mouth. Holding this glass firmly in place with one hand, invert the bottle over the dish of water with the other hand. Remove the glass top when the mouth of the bottle is under water. Now blow air through the bent glass tube into the bottle (Fig. 258).

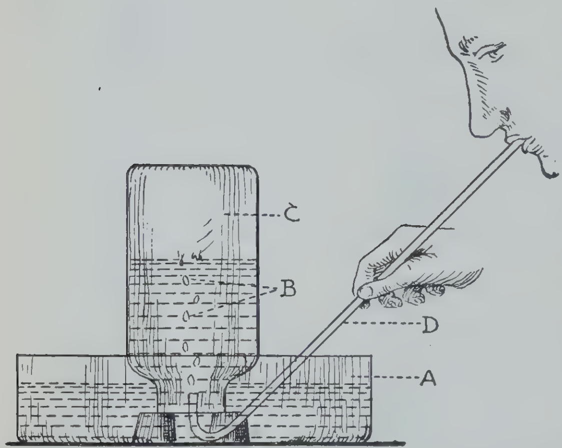


Fig. 258 A, Flat dish containing water. B, Air bubbles going up through the water. C, Air. D, Bent glass tube. Why does the water leave the bottle as the air enters?

Observation.—Does some of the water leave the bottle when air collects in it?

Conclusion.—When air enters the bottle does it take up space?

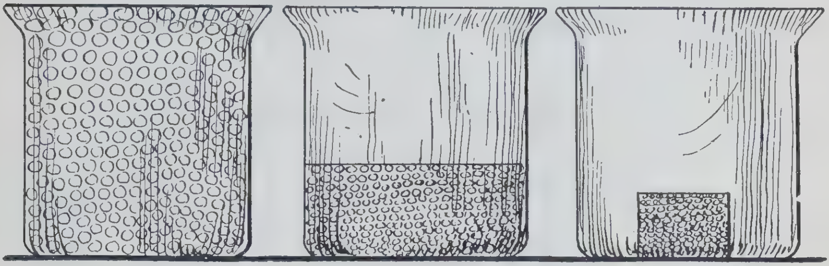
NOTE. — The bubbles of air entering the bottle rise to the top because they are *pushed up* by the heavier water around them; *i.e.* they float to the surface.

Air occupies space.—From these experiments we learn that air occupies space. It is therefore a form of matter. Because air occupies space, it must be allowed to escape from a vessel when we pour something else into it; and when a liquid is poured out of a vessel, such as a bottle or an oil can, air rushes in and takes the place of the material that is running out. If the vessel has a single small opening, the air rushes past the liquid into the vessel, interfering with the steady flow, and causing a gurgling sound. If the opening of the vessel is large, the air flows in silently.

Because air is invisible, it is hard for us to think of it as matter. It may be easier for us to do so if we consider, for a moment, the nature of matter.

What matter is like.—Everything about us that occupies space, whether visible or invisible, is a form of matter. It may be a **solid,** such as wood, stone, iron, or glass; it may be a **liquid,** such as water, gasoline, or milk; or it may be a **gas,** such as air.

All matter, whether solid, liquid, or gas, is made up of tiny particles called **molecules.** These molecules, which are



A B C

Fig. 259.

Diagram to illustrate molecules of a gas within a vessel. Molecules, of course, cannot actually be seen. This beaker is covered with glass.

Diagram to illustrate molecules of a liquid within a vessel. Do the molecules of a liquid always occupy the whole space within a vessel?

Diagram to illustrate molecules of a solid within a vessel. Why does a solid retain its own shape and not become the shape of the containing vessel?

so small that they cannot be seen with the most powerful microscope, are in constant motion, bouncing away from one another. The *molecules of a gas* (Fig. 259, A) bounce away from one another and spread out sufficiently to fill the whole space in which the gas is contained. Molecules of air in a room, for example, spread throughout the whole room. The *molecules of a liquid* (Fig. 259, B) also move about but are held much closer together. Placed in a vessel, they will move freely around one another and collect in the lower part of the containing vessel. A liquid, therefore, takes the same shape as the vessel into which it is poured. The *molecules of a solid* (Fig. 259, C) are held much

more firmly together than those of a gas or a liquid and are therefore more limited in their movements. For this reason, a solid retains its own shape no matter what may be the shape of the vessel in which it is contained.

Why cannot we see air?—While individual molecules of matter cannot be seen, great numbers of them, grouped closely together, become visible. This explains why solids and liquids, whose molecules are always close together, are visible, while gases, such as air, whose molecules are relatively far apart, may be invisible. Air, in liquid form, can be seen.

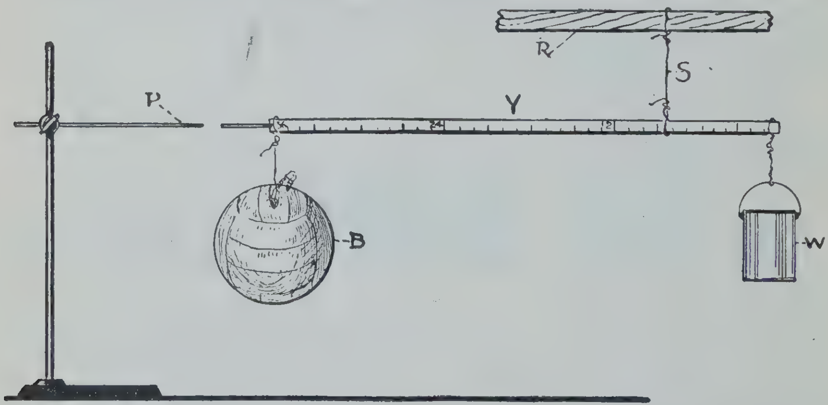


Fig. 260. Y, Ruler about a yard long. S, Strong cord. R, Any rigid or firm support. B, Ball. P, Pointer. If the weight (W), which consists of a can with some sand in it, does not exactly balance the weight of the ball, slide the ball slightly along the ruler until the two become balanced.

PROBLEM II. HAS AIR WEIGHT?

We have proved that air, although invisible, is matter by showing that it *occupies space*. We can also prove that air is matter if we can show that it *has weight*.

Experiment I

Object.—To discover whether air has weight.

Apparatus.—A football or basketball, a yard ruler (any light stick about a yard long will do), a heavy weight (a can about quart size with sand or stones in it makes an excellent weight), a strong cord, a tall stand, a pointer, a pin.

Method.—Tie one end of the piece of cord around the yard ruler about a foot from one end and fasten the other end to a rigid support (Fig. 260). At the end of the ruler nearer to the string tie a weight sufficiently heavy to balance the football blown up tightly with a bicycle pump[1] and hung near the other end of the ruler. (After blowing up the ball, tie a string or wrap an elastic around the tube of the bladder, and allow the tube to protrude through the case of the ball.) Push a pin a short way into the end of the ruler nearer the ball, and exactly opposite the pin station the pointer as shown. Now allow air to escape from the ball. When the ruler stops moving, notice whether the pin stands opposite the pointer.

Observations. — (1) Does the end of the ruler that supports the ball rise when the air escapes? (2) Does it rise very far?

Conclusions. — (1) Does the ball become any lighter when some of the air within it escapes? (2) Does it become very much lighter? (3) Do you think air is very heavy? (4) Has air weight?

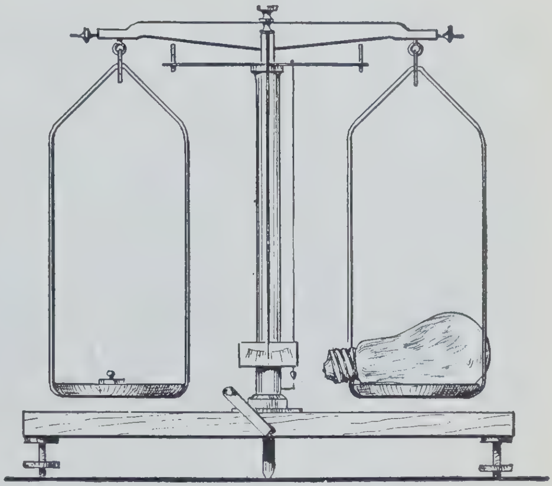


Fig. 261. Balance. Enough weights are placed in the one scale pan to balance exactly the weight of the electric light bulb lying in the other scale pan.

Experiment II

If you have a balance that will give fairly accurate reading, a burned-out electric light bulb (an electric light bulb has had air taken out of it), and a blow-pipe, you can easily find out whether air has weight. (Avoid "Nitrogen" bulbs in this experiment.)

Method.—Carefully balance the bulb on the scales by means of weights. Without removing the bulb from the scales, melt a hole through it by blowing a small flame (with the blow-pipe) against one point on the glass (Fig. 261).

Observation.—When a hole is melted through the glass, allowing air to enter, does the bulb become heavier?

Conclusion.—Has air weight?

[1]If the pump has no valve at the outlet, pinch the tube during the up stroke.

NOTE.—By again balancing the bulb with weights, and noticing what weights have to be added, you can find the weight of the air that entered.

How much does air weigh?—By either one of the two experiments recorded above you can learn that air has weight, and therefore is matter. Its weight is very little compared with that of solids and liquids. (Can you explain why?) A cubic foot of water weighs about 62½ pounds, a cubic foot of iron weighs about 440 pounds, but a cubic foot of the ordinary air about us weighs only about 1¼ *ounces*.

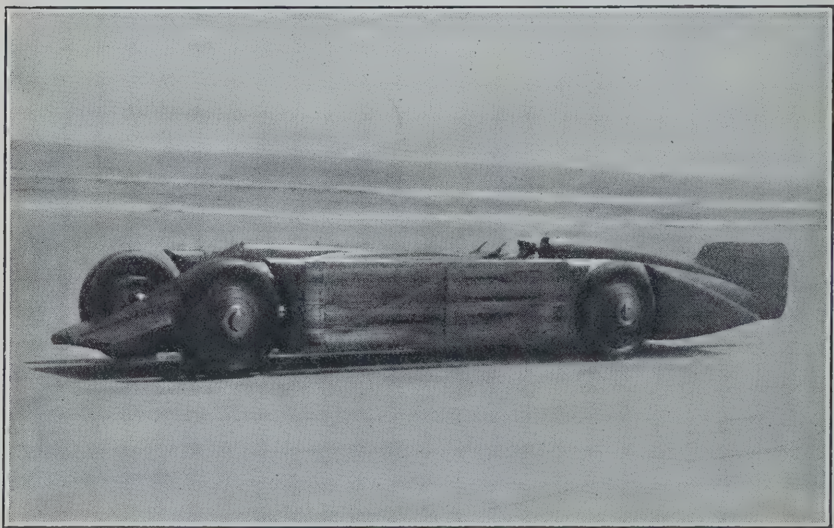


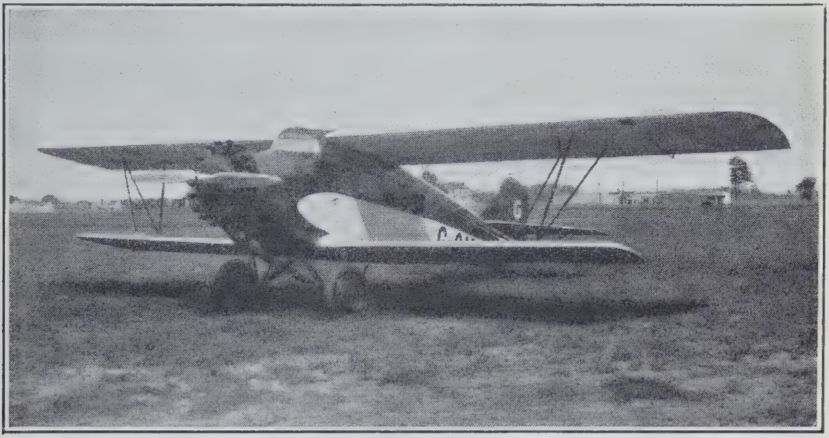
Fig. 262. The "Golden Arrow". This racing car is so shaped that the air offers the least possible resistance to its rapid movement. It was driven by Major Seagrave at more than two hundred and thirty miles an hour.

PROBLEM III. DOES AIR OFFER RESISTANCE?

Any one who has tried to ride a bicycle against a strong wind can answer the question, "Does air offer resistance?" A racing car is constructed in such a way as to strike as little air as possible when moving along rapidly (Fig. 262).

The resistance offered by the wind to a flying kite holds up the kite. When the wings of an aeroplane are moved

rapidly forward through the air, the air offers sufficient resistance to hold up the plane, although it may weigh a few tons (Fig. 263). Steel rails can resist the weight of a great locomotive, a body of water can hold up or resist the weight of an immense ocean liner, and air can resist the weight of an aeroplane. The steel rails, which are solid, the water, which is a liquid, and the air, which is a gas, all offer resistance, and for this reason they are all said to be forms of matter.



Courtesy National Air Transport, Ltd.

Fig. 263. Air resistance prevents this heavy aeroplane from falling to the earth when it is drawn rapidly forward by the propeller.

Review

(1) Why has so little been known about air until recent times? (2) How would you know matter even if you could not see it? (3) Outline an experiment to show that air occupies space. (4) Why does water run out of an inverted bottle in gushes? (5) What are molecules? (6) Why are some substances visible while others are not? (7) Show, by an experiment, that air has weight. (8) Measure your classroom or sleeping room, and find out how many cubic feet of air it contains. Then calculate the approximate weight of air in the room. (9) If you have the opportunity, weigh an empty automobile tire. Then blow it up tightly and weigh it again. Does it become heavier when much air is pumped into the tire? What does this prove? (10) How many times as heavy as air is water?

How many times as heavy as air is iron? (Consult a Physics text.) (11) How do you know from experience that air offers resistance? (12) What holds a kite in the air on a windy day? On a windy day, the molecules of the gases that together make up the air move rapidly (blow) against the face of a kite. Make a diagram of a kite flying in the air, held by a string. This may be done by drawing diagonally across a sheet of paper a line two or three inches long. Running down from a point somewhat above the centre of this line, make a second line almost at right angles to the first one. This will represent the string on the kite. To represent the air moving against the kite, draw three or four arrows parallel to the bottom of the sheet of paper but pointing towards different points on the face of the kite. In what two directions will the molecules forming the air tend to move the kite? Will the air blowing against the kite offer resistance to anyone pulling forward and downward upon the string that is attached to the kite? Why will a kite not fly on a calm day? (13) What holds up an aeroplane? Why can it fly on a calm day while a kite cannot? (14) Give three reasons for believing that air is matter. (15) How would you define matter?

CHAPTER XXXIV

AIR PRESSURE

What we mean by "pressure per square inch."—Let us suppose that your weight is 100 pounds. When you stand on the floor, how much do you press downward upon it? If your shoes touch ten square inches of the floor, how much do you press down on each square inch? In this case we would say that the pressure that you exert upon the floor is ten pounds on each square inch or "ten pounds per square inch."

If you stand with all your weight on one foot, what is then the pressure per square inch upon the floor? If you stand on a piece of wood one inch square, what pressure per square inch would you exert upon it? You now understand what we mean by "pressure" and by "pressure per square inch."

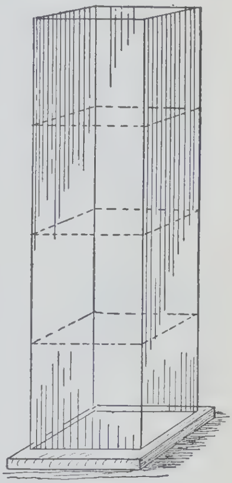


Fig. 264. This tank of water is one foot square and four feet high. What is the pressure per square inch on the bottom of the tank? Pearl divers go down in the sea to a maximum depth of 150 feet in search of oysters and pearls. What is the pressure of water on each square inch of their bodies at that depth?

Pressure under a liquid.—The tank shown in Figure 264 is one foot square. If it is filled with water to a depth of four feet, how many cubic feet of water does it contain? A cubic foot of water weighs about 62½ pounds. What is the pressure of water on the one square foot of surface at the bottom of the tank? What is the pressure on each square inch of the bottom? If you were under water at a depth of four feet, what would be the pressure of the water upon a square foot of your body?

What would be the pressure per square inch? What would be the pressure at a depth of twenty feet? What would be the pressure at the bottom of the ocean, where it is two miles deep? Divers, when they come to the surface after having been down deep into the water, suffer greatly as a result of the decrease in pressure.

Pressure under the ocean of air.—Surrounding the earth is a great ocean of air many miles in depth. It is called the **atmosphere.** We live at the bottom of this ocean of air just as fish may live at the bottom of an ocean of water. Does this air press upon our bodies just as water presses on the bodies of divers and fish?

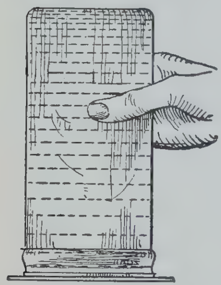


Fig. 265. What prevents the water and paper cover from falling from the jar?

Experiment I

Object.—To find out whether air (the atmosphere) exerts pressure. (First method.)

Apparatus.—A pint or quart sealer, water, a piece of thin cardboard or heavy paper (Fig. 265).

Method.—Completely fill the sealer with water. Cut a piece of the thin cardboard, making it about an inch larger in diameter than the mouth of the sealer. Wet it thoroughly with water and place it over the mouth of the jar. Seize the bottom of the sealer of water with the right hand, put the other hand flat upon the cardboard cover, and completely invert the jar. Holding the sealer firmly with the right hand, carefully remove the left hand from the cover.

Observation.—Do the paper cover and the water fall when the support of the left hand is removed?

Conclusions.—(1) What must be pressing against the cover to hold up both the cover and the water? (2) Has air pressure?

Note.—If you have a vessel much taller than the sealer but not much larger in diameter, repeat the experiment, using the taller vessel to discover whether the pressure of the air is sufficient to hold up a column of water taller than a sealer.

Experiment II

Object.—To find out whether air exerts pressure. (A second method.)

Apparatus.—A piece of glass tubing open at both ends and six inches long, a quart sealer, water (Fig. 266).

Method.—Fill the sealer with water and place the glass tube in it. Then put a finger tightly over one end of the tube, raise it to a vertical position, keeping the other end under water, and finally lift it up from the water. After a moment remove the finger from the top of the tube.

Observations. — (1) Does the water remain in the tube as long as the finger is held firmly on the top? (2) Does it run out when the finger is removed?

Conclusions. — (1) What is holding the water up in the tube? (2) Why does the water run out when the finger is removed? (3) Does air (the atmosphere) exert pressure?

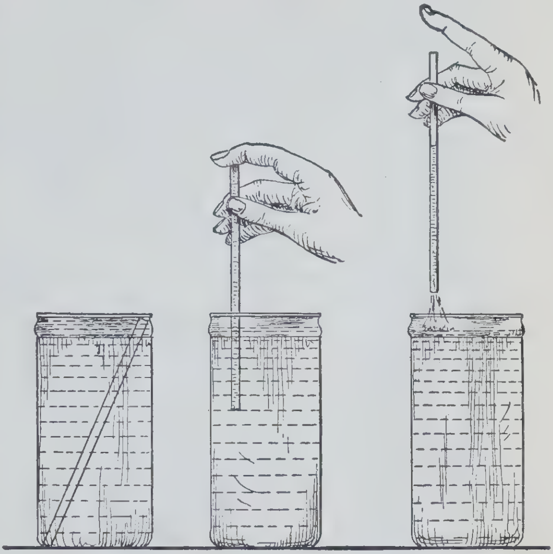


Fig. 266. What holds the water up in the glass tube shown in the middle diagram? Would it run out if the finger were removed from the top end of this tube? Why?

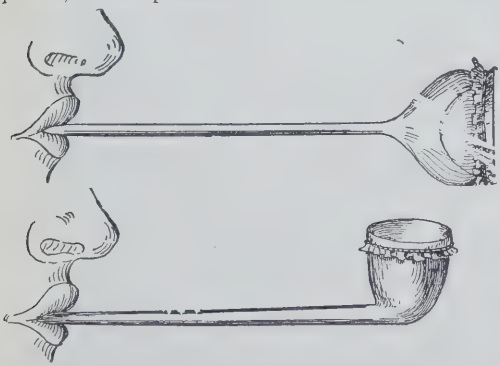


Fig. 267. Thistle-tube and clay pipe with a thin piece of rubber stretched and attached over the large end of each. Why do the pieces of rubber bend inward when air is sucked from the tubes?

Experiment III

Object. — To find out whether air exerts pressure. (A third method.)

Apparatus.—A thistle-tube or a clay pipe, a piece of thin rubber (a piece of a toy balloon will do), a piece of string (Fig. 267).

Method. — Stretch the rubber over the mouth of the thistle-tube or of the bowl of the clay pipe. Tie the string tightly around it just below the rim. Remove the air from the tube or the pipe by suction with the mouth. Point the apparatus in all directions. Then let the air into the apparatus again.

Observations.—(1) Does the rubber stretch down into the thistle-tube or the bowl of the pipe when the air inside is removed? (2) Does it remain stretched when the apparatus is pointed in all directions? Is it stretched to about the same extent when turned in each direction? (3) Does the rubber come out again when air is admitted?

Conclusions.—(1) When air is removed from one side of the rubber by suction, what forces the rubber in? (2) Why is it not forced in before suction commences? (3) Is the pressure of air exerted in all directions and to about the same extent?

Experiment IV

Object.—To find out whether air (the atmosphere) exerts pressure. (A fourth method.)

Apparatus.—A paper bag (Fig. 268).

Method.—Thrust the finger of one hand into the end of the paper bag and with the other hand close the mouth of the bag around the finger. Remove the finger. Using your mouth, blow enough air through the finger hole to fill completely and extend the bag. Now remove air from it by suction with the mouth.

Fig. 268. Paper bag.

Observation.—Does the bag collapse?

Conclusions.—(1) What forces the bag in when the air is removed? (2) Why was it not forced in before removing the air? (3) Has air pressure?

Why does air exert pressure?—The atmosphere of the earth extends outward from it a distance of over 100 miles. This is shown by meteors which at that distance from the earth become red or white hot by friction as they pass through the air. You may have observed these meteors at night. We call them falling stars. The air (the atmosphere), as we have learned, has weight. While one cubic foot of air may weigh little, a column of air standing upon an area of one square foot on the ground and 100 miles in depth would weigh a good deal. This air would therefore exert considerable pressure on any object upon the earth.

Air, as we have also learned, exerts pressure. The bottom layers of the atmosphere are holding up the weight of the

Fig. 269. The Magdeburg experiment.

air above. We therefore live surrounded by air which is pressing inward upon us. There is air not only outside our bodies but also inside our bodies, in the lungs, in the blood, and in the cells of which we are composed. On the outside, it presses against our bodies with a force of nearly fifteen pounds on each square inch. (Estimate the pressure on your whole body.) On the inside, fortunately, it presses outward with an equal force. Because the pressure outward is the same as that inward, we feel no pressure of the air at all. It is therefore hard to believe that, if the air within our bodies were suddenly pumped out, we should be crushed to death. The pressure upon us would then be greater than that of the wheel of a heavy steam tractor passing over us. It is equally hard to believe that, if we were suddenly to place ourselves in a room in which there was no air pressure, the pressure of the air within our bodies would be great enough to cause us to explode.

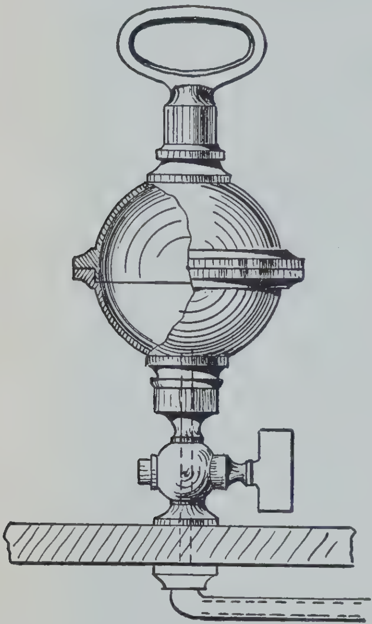


Fig. 270. Pair of Magdeburg hemispheres placed on an air-pump. Why is it difficult to pull them apart when the air is pumped out of them?

Mountain climbers and aeroplane pilots actually experience something of what air pressure means because, when they ascend to high altitudes, they often find that their noses bleed. At the foot of the mountain, the pressure of the air within the body of a mountain climber is the same as that of the air outside the body. Similarly, on the ground, the pressure is the same within and without the body of an air-

man. When the climber or the airman ascends from the low to the high altitude, the pressure inside his body does not decrease as rapidly as the pressure outside. The pressure within the body is then greater than the pressure outside. This unequal pressure often causes some of the thin blood vessels of the nose to burst, resulting in bleeding.

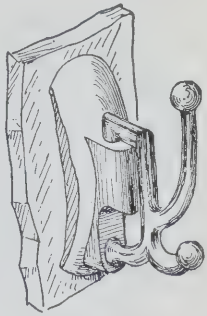


Fig. 271. Coat hook. What holds the rubber pad firmly to the glass? A piece is cut away from one side of this pad to show its shape.

Magdeburg hemispheres.—A very striking demonstration of how great air pressure is was made before the German Emperor Ferdinand and the Reichstag as long ago as 1654. Guericke, Mayor of Magdeburg, who performed the experiment, used a hollow sphere twenty-two inches in interior diameter made of two hemispheres (Fig. 269). He placed the lips of the two hemispheres together, exhausted the air from between them by an air pump, and used horses to pull in opposite directions upon them. Sixteen horses in all, half pulling each way, were required to overcome the pressure of the air upon the outside of the sphere and thus separate the two halves.

If there is in your school a pair of Magdeburg hemispheres similar to those shown in the diagram (Fig. 270) and an air pump, exhaust the air from between them and endeavor to draw them apart.

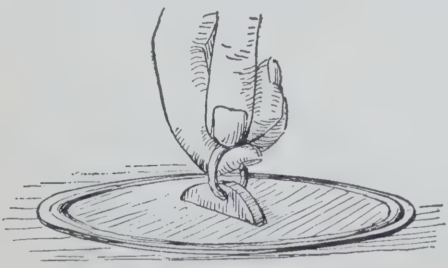


Fig. 272. Rubber sink-stopper.

Problems

(1) A coat hanger is sometimes made by attaching a hook to a hollowed rubber pad which is pressed against any smooth surface such as glass (Fig. 271). Explain how the rubber pad is held against the surface sufficiently strongly to

support a coat. (2) A flat rubber sink stopper, wet and pressed tightly against a flat table (Fig. 272), cannot be pulled off easily. Explain.

Review Questions

(1) Describe an experiment to show that the air (atmosphere) exerts pressure. (2) Account for air pressure. (3) Why do airmen and mountain climbers sometimes have nose-bleed when they ascend to high altitudes? (4) What was demonstrated by the original pair of Magdeburg hemispheres? (5) If the body of an average man has fifteen square feet of surface, what is the total pressure of the atmosphere upon him? (Assume air pressure to be fifteen pounds per square inch.) Why are our bodies not crushed by this great pressure?

CHAPTER XXXV

COMPRESSED AIR

Air, we have learned, is matter, in the form of a gas and made up of a great many tiny molecules. Each of the molecules is so small that it cannot be seen. These molecules move about continually, bouncing off one another and striking against the walls of any vessel in which the air is contained. Moreover, we have been informed that molecules of matter, when in the form of a *gas*, are farther apart than when the same matter is in the form of a liquid or solid. With these ideas in mind, let us see whether the molecules of air can be squeezed or compressed closer together.

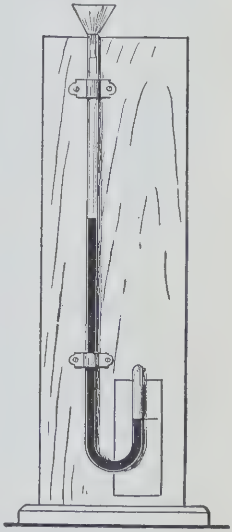


Fig. 273. Does the column of air within the closed end of the bent tube become shorter (compressed) as more and more weight of mercury is poured into the long arm of the tube?

Experiment I

Object.—To discover whether air can be compressed. (First method.)

Apparatus.—A glass tube about three and a half feet long bent in the form of the letter J, with the short end of the tube closed, mercury in a dish, a stand.

Method.—Pour a little of the mercury into the bent tube. Then tip the tube over on its side sufficiently to allow a little air, entrapped in the short arm of the bent tube, to escape past the mercury. Then mount the tube on the stand as shown in the diagram (Fig. 273) or place it on a metal stand. After marking the level of the top of the mercury in the short tube by means of an ink line on the glass or on a piece of paper attached to the tube, slowly pour mercury into the long arm.

Observation.—Does the volume of air entrapped in the short arm of the bent tube vary as more and more mercury presses upon it?

Conclusion.—Can air be compressed?

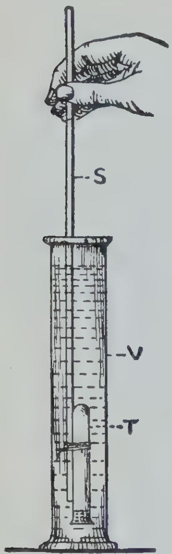


Fig. 274. S, Stick. V, Tall vessel of water. T, Test-tube tied to the stick, mouth downward. Does any water enter the test-tube as it is forced downward in the water? What does this show?

NOTE.—Pour out some of the mercury again, being careful to allow no air to escape from the closed end of the tube. Notice whether the volume of the enclosed air increases as the pressure upon it is thus decreased. Will air expand when the pressure upon it is decreased? Is it therefore elastic?

Experiment II

Object.—To see whether air can be compressed. (A second method.)

Apparatus.—A tall glass vessel nearly filled with water, a test-tube, a small stick about two feet long, a piece of string (Fig. 274).

Method.—Tie the test-tube near one end of the stick, with the mouth of the test-tube a little beyond the end. By means of the stick, push the test-tube down deep into the water within the tall glass vessel. Notice whether the water enters the test-tube as it descends. Then draw the test-tube up towards the surface again and notice any change in the level of the water within the test-tube.

Observations. — (1) Is the air within the test-tube compressed into smaller volume as it descends in the water? (2) As the test-tube is raised, thus reducing the pressure of water on the contained air, does the air expand again?

Conclusions. — (1) Is air compressible? (2) Will air stretch or expand? Is it therefore elastic?

Fig. 275. Bicycle pump.

Experiment III

Object.—To see if air can be compressed. (A third method.)

Apparatus.—A football (or basketball), a bicycle pump, a glass tube about fifteen inches long, bent at one end and large enough to fit tightly into the rubber tube of a football bladder, a pint sealer, a flat dish partly filled with water (Figs. 275 and 276).

Method.—Using the bicycle pump, blow up the football tightly with air. (After each downward stroke of the piston of the bicycle pump,

pinch the rubber tube of the ball while pulling back the piston. This will prevent air within the ball from going back into the pump during the upward stroke.) Then near the bladder pinch the tube of the ball with your thumb and finger to prevent air from escaping, detach the pump, and push the straight end of the glass tube into the rubber tube of the ball. See that the rubber tube fits tightly over it. (It may be made quite tight by binding with elastic or string.)

Fill the pint jar with water. Place its glass cover with rubber ring over it and invert it over a dish of water, putting the mouth of the jar below the level of the water in the dish. Remove the glass cover. Now

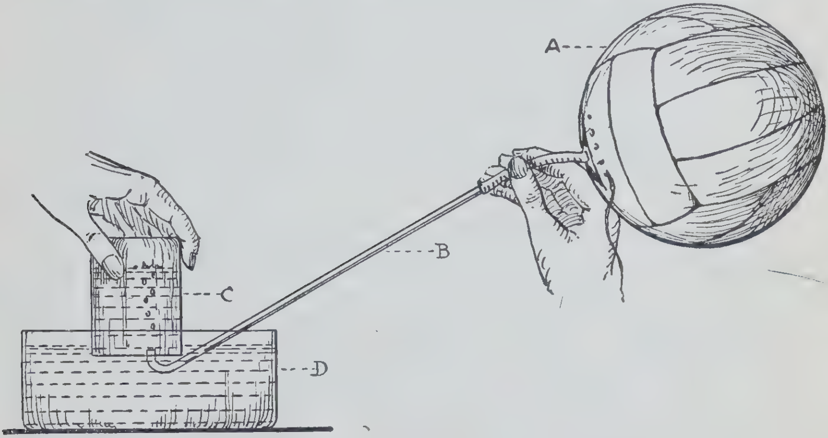


Fig. 276. A, Football. B, Glass tube bent up at one end. C, Pint sealer. D, Dish partly filled with water. Will the air contained in a football tightly blown up occupy a larger volume when collected in the sealer? Why?

thrust the bent end of the glass tube under the jar of water and allow enough air to escape very slowly from the ball to fill the jar. Then pinch the tube to prevent further escape of air. Again fill the jar with water, invert it over the dish of water, and fill it with air from the ball in the same manner as before. Repeat this operation again and again until no more air will escape from the ball. Count the number of jars of air collected. (Put the same number of jars of water in a pail to see how large a space it occupies.)

Observation.—Is the volume of the water in the pail greater than the volume of the ball? How does the total volume of air that escapes from the ball compare with the volume of the ball itself?

NOTE.—This method may be modified by allowing the air to escape from the ball into toy balloons. Compare the volume of the air in the balloons with the volume of the air in the ball.

Conclusions.—(1) Can air be compressed? (2) When air is compressed, does it remain compressed or will it expand again when it is released from the pressure? Is it therefore elastic?

Air can be compressed.—When pressure is exerted on air, its molecules become squeezed or compressed closer together. In the first two experiments recorded above, the molecules of air must have been compressed closer together by the pressure exerted upon them because the volume of the air in each case decreased. In the last experiment, we found that each time the piston of the bicycle pump was forced down it squeezed or compressed air into the ball. In this way a great many molecules of gas were compressed into the small space within the ball. Just how much air was compressed within the ball was clearly shown by allowing it to escape and fill jar after jar. Because the total volume of air collected in the jars was several times that of the ball itself, we must conclude that air can be greatly compressed.

Air is elastic.—When a handful of loose snow is compressed between the hands, it is squeezed into much smaller volume. When the pressure of the hands is removed, the snow does not immediately expand again. Air, however, behaves quite differently. Our experiments show that compressed air will expand again when the pressure, which squeezes it together, is removed. Air, therefore, unlike snow, is elastic. We say that it has "spring" or *elasticity.*

Review

(1) Describe an experiment to show that air can be compressed. (2) Show that the air tightly compressed within a football will occupy many times the volume of the ball when not compressed more than the air within a room. (3) Anything that will stretch or spring back is said to be elastic. Illustrate in two or more ways that air is elastic.

CHAPTER XXXVI

USES OF COMPRESSED AIR

Compressed air can be used for a variety of purposes, but only a few of them can be mentioned in this chapter.

1. In tires and balls.—If you press down upon a coil spring and then suddenly release it, it will "spring" back. In the same way, if you press your thumb against a bicycle tire or a football, filled with compressed air, you may bulge it inwards, but the walls of the tire or ball will spring back when the pressure of the thumb is removed. This happens because air is elastic.

When a car runs over a small stone on the road, we receive very little jolt because the stone, instead of suddenly lifting the car, simply forces the wall of the tire inward and compresses the air within it. When the wheel has passed over the stone, the compressed air within the tire, being elastic, causes the wall of the tire to spring out again to its original shape.

2. In brakes.—How is a railway engineer able to put sufficient pressure on the brakes to stop a passenger train almost within its own length, even though the train may weigh hundreds of tons and be travelling rapidly? How does the motorman on a street car stop the car as quickly as he does?

Each engine, railway coach, and street car is equipped with a reservoir into which air is forced by a small pump until it is greatly compressed. In the case of a train, the pump is on the engine. Have you heard or seen it working on an engine standing at a station? A line leads from the air pump to the reservoirs on the coaches. Have

you ever seen a brakeman couple the air line (a rubber hose) when a car is attached to a train? When an engineer wishes to stop his train, he applies the brakes by means of compressed air. He does this by opening a valve or tap on the air line which allows compressed air from the reservoir on each car to force the brakes against the wheels. On a railway car standing at a station look for the reservoir and brake blocks. If at any time the air line between the

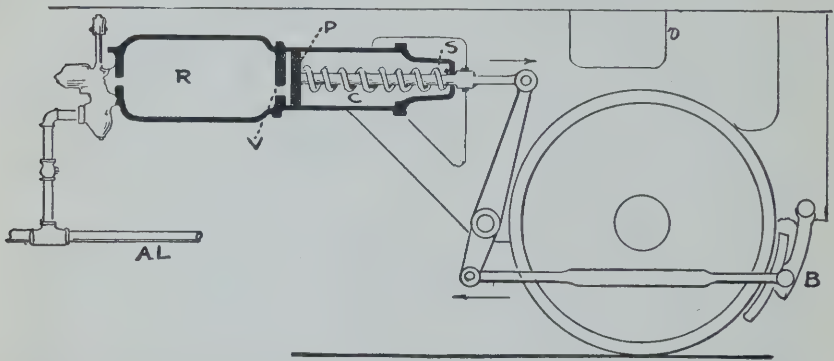


Fig. 277. Air brakes on a car. Air, compressed by a pump in the engine of a train, is carried to the various cars by the air line (AL) and stored in reservoirs, one for each car. When compressed air is allowed to pass through the valve (V) from the reservoir (R) into the cylinder (C), it forces back the piston (P) and, by means of levers, applies the brake (B) to the wheel. When the compressed air is allowed to escape from the cylinder, the spring (S) pushes the piston back again and releases the brake from the wheel. The air brake was invented by George Westinghouse in 1872.

engine and the cars becomes broken or disconnected, the brakes are automatically forced against the wheels. Suggest the advantage of this.

3. In air guns.—In an air gun there is a little cylinder and a piston. By bending down the stock of the gun the piston is pulled back, compressing a spring (Fig. 278). The piston is then held back by means of a trigger. When the trigger is pressed, it releases the spring and allows it to push the piston suddenly forward. This compresses the air in the cylinder in front of the piston. Leading from the front end of the cylinder is a small tube in which the shot is placed.

The compressed air rushes out through this tube, driving the shot before it.

4. In pneumatic hammers and drills.—The framework of many buildings and ships is made of pieces of metal rivetted together. Frequently the rivetting is done by hammers driven by compressed air. In the mining areas much of the earth and rock is cut by means of drills driven by compressed air. These drills are also used to cut through cement roads when cables or pipes have to be placed underneath them or repaired (Fig. 279). By a simple device the compressed air makes these hammers and

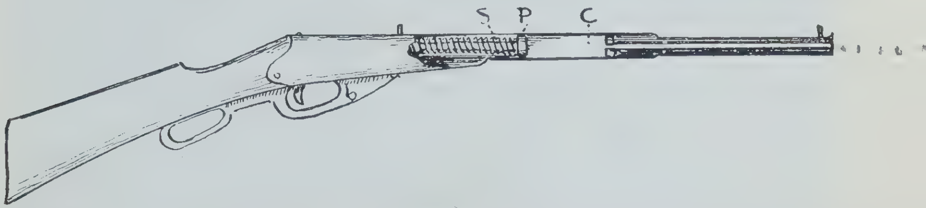


Fig. 278. Air gun. S, Spring. P, Piston. C, Cylinder. When the piston is pulled back, the spring is forced into small space. When the trigger is drawn, the spring drives the piston forward rapidly. This compresses the air within the cylinder. The compressed air escapes as rapidly as it can through the opening in the barrel. If a pellet is placed in the barrel of the gun before the trigger is released, it will be driven rapidly out of the gun by means of the compressed air.

drills move up and down rapidly with considerable force. In a moment a bolt is rivetted or a hole is drilled.

Air for these machines is pumped into heavy steel tanks by means of engines. From the tanks, the compressed air can be led through flexible pipes to any place where it is required. At one time you may see a pneumatic hammer rivetting high up in the framework of a building; at another time you may see a drill at work down in a deep trench or hole in the rock.

5. In submarines (*sub*, under, *mer*, the sea).—A submarine is a boat so constructed that it can be made to sink completely below the surface of the water in which it is floating, and be brought up to the top again at will (Fig.

280). To make the boat sink, some of the water in which the boat is floating is allowed to enter large tanks, called ballast tanks, within the boat. The weight of this water makes the boat so heavy that it sinks below the surface. To lighten the boat so that it will rise to the surface again, the water within the ballast tanks is forced out by means of

Courtesy Canadian Ingersoll-Rand Co., Ltd.

Fig. 279. This compressed air machine is being used to cut through the pavement on a street.

compressed air stored in cylinders within the boat. Compressed air within these boats also supplies the sailors with air for breathing.

6. In diving bells.—From the experiments that you have performed with air, can you suggest any method whereby you could go down into the sea to level a place on the sea bottom preparatory to laying a foundation upon it?

The fact that water does not enter a vessel, such as a tumbler, to any extent when it is inverted and pushed down into a dish of water (see experiment, page 314) probably suggested the idea of constructing a diving bell for work under the sea.

The ordinary diving bell consists of a bottomless chamber, constructed of very heavy iron or steel and more or less bell-shaped. Seats, on which the men can sit, are attached

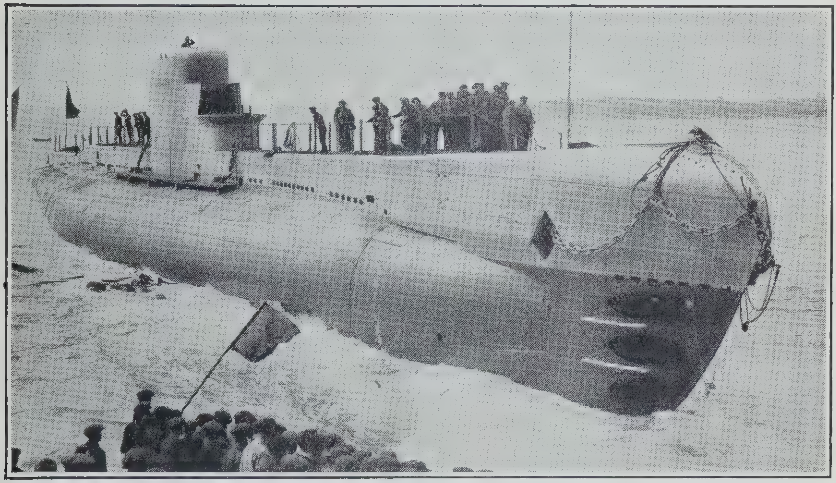


Fig. 280. Submarine. This boat contains tanks for compressed air. Would the air be pumped into these tanks when the boat is at the surface or when it is under the sea? What use is made of compressed air in a submarine?

around the inside walls, and the required tools for excavation purposes are hung on hooks along the walls. By means of cables this large bell is lowered and raised from a ship especially constructed for the purpose (Fig. 281).

The pressure of water increases with depth at the rate of nearly half a pound to every foot. Therefore, if a diving bell were lowered into the sea as we lowered the test-tube into the water (see Fig. 274), the air within the bell would be compressed, and water would gradually enter it at the bottom. At a depth of thirty feet, for example, the air

would be compressed to half its volume, and the bell would therefore be half filled with water. The men could not work with this water in the bell. To prevent water from entering the bell, therefore, more air is forced into it as it is lowered.

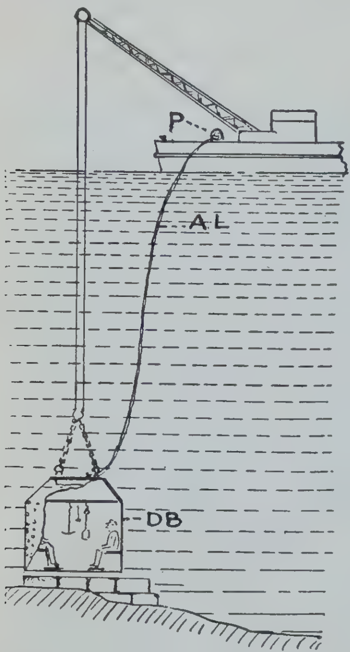


Fig. 281. Diving bell. P, Pump of the ship to compress air into a reservoir. Compressed air is taken from the reservoir to the diving bell (DB) by means of the air line (AL). This compressed air within the diving bell prevents water from entering the bottom of the bell and allows the men within the bell to work on the foundation beneath them. When exposed to a *rapid* increase or decrease of air pressure, men become seriously ill. Therefore, as the diving bell is raised or lowered, the air pressure is changed very slowly.

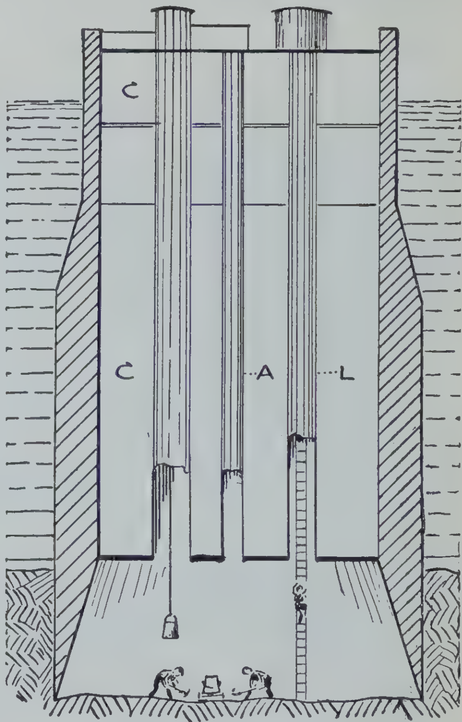


Fig. 282. Diagram of caisson used when building the Forth Bridge in Scotland. C, Air-tight chambers. A, Air line. L, Large tube through which the men entered and left the caisson. Compressed air was forced through the air line (a tube) into the large chamber shown at the bottom of the caisson. The compressed air prevented water and mud from entering the chamber and thus enabled the men to do the digging and afterwards lay the foundation for the bridge.

Pumps on the ship compress air into a reservoir, from which it is led through a flexible pipe down to the diving bell, thus supplying the required amount of air to keep water out of the bell.

When the bell is lowered to the bottom of the sea, the men may do any work required. Pneumatic drills are used when digging in rock under the bell. The compressed air for these is supplied from the ship by a separate air tube. Soil or rock dug from the bottom of the sea is thrown into a large vessel hung from the roof of the diving bell.

7. In caissons.—In order to reach solid rock on which to place the foundations of tall buildings and bridges, excavations sometimes have to be made quite deep. It frequently happens that water runs into an excavation just as it may run into a well. Further digging then becomes impossible until a caisson, similar in principle to a diving bell, has been sunk down. Compressed air within a chamber which is open at the bottom prevents the water and mud from entering the caisson. Within this chamber the men do the excavating and later construct the foundation.

Review

(1) Give two reasons why air is suitable for use in tires. (2) Is it possible to press in the wall of a football tightly blown up? Explain. (3) Enumerate several uses made of compressed air. Study each use sufficiently to be able to explain (*a*) how brakes are applied to the wheels of a train, (*b*) how an air gun works, (*c*) what pneumatic hammers and drills are used for and why they are very useful, (*d*) how a submarine can be lowered and raised again, (*e*) the principle and use of a diving bell or caisson.

CHAPTER XXXVII

AIR PRESSURE AT WORK

I. DRINKING BY SUCTION

Did you ever watch a horse or a cow take a drink of water? If it is drinking from a stream, its mouth may be almost on a level with its feet when it reaches the water. The water which it drinks must then flow upward into its mouth and throat. How can water "flow *up hill*" in this way? At some time or other you may have gone to a pump for water. Did you ever enquire why the water flows through the pump?

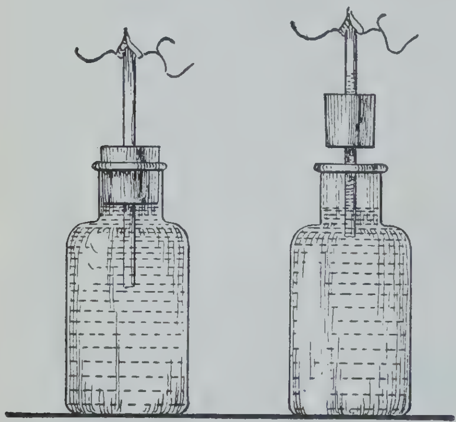


Fig. 283. From which bottle can water be sucked up into the mouth? Why?

Experiment

Object. — To discover one reason why water may "flow up hill."

Apparatus.—A clean bottle, a one-holed stopper for it, a piece of clean glass tubing about eight inches long that fits tightly into the stopper, a little water (Fig. 283).

Method.—Fill the bottle with water. Push the glass tube through the hole in the stopper for a distance of about three inches. Put the end of the glass tube that is below the cork down into the water in the bottle, leaving the cork above the mouth of the bottle. Place your mouth over the glass tubing and try to suck water up through it. Fill the bottle again, insert the cork tightly in the bottle, and try again to suck the water up.

Observation.—In which case does the water flow up the glass tube into the mouth?

Conclusions.—(1) In this experiment, when you suck with your mouth, you simply enlarge the mouth cavity. This allows the air in the mouth and in the glass tube to spread out and occupy this enlarged space. When it does this, its pressure is reduced. The pressure of the air on the surface of the water in the tube is then less than the pressure of the air on the surface of the water in the bottle when the cork is out. Why does the water then flow up into the mouth? (2) When we put the stopper in the bottle, can the outside air then press upon the water in the bottle? Now, if we reduce the pressure within the tube by suction, why will the water not rise? (3) Is air pressure necessary to permit sucking water up a tube with the mouth?

Upon what does drinking by suction depend?—In this experiment the pressure of the air within the mouth and the glass tube is reduced by suction. As a result of this, the greater pressure of the air outside upon the surface of the water in the bottle forces the water up the tube into the mouth.

Drinking by suction, therefore, depends upon air pressure. When a person lies down by a spring or stream and puts his mouth to the water for a drink, or when a deer stands by a pond and gets water, the lips of the mouth are first formed into a tube. Air pressure within this tube is then reduced by enlarging the mouth cavity, and the pressure of the air on the surface of the water outside the tube forces water up into the mouth. In this way water is forced to "flow up hill."

Review

(1) Describe an experiment to show that, when we suck water up through a glass tube, or lemonade up through a straw, it is air pressure that causes them to flow up into the mouth. (2) What must an animal, such as a horse or cow, do to enable it to take a drink from a stream? Does a bird drink in this way? Watch a chicken and a pigeon drinking.

II. THE LIFT PUMP

If you live in the city, you may not be familiar with a common lift pump. In the country and in many towns and villages, water is obtained from cisterns and wells, usually

by means of lift pumps. Perhaps you have used a pump to obtain water. Do you understand why the water rises in the pump?

Experiment

Object.—To discover why water flows up into the cylinder of a pump.

Apparatus.—A piece of glass tubing about half to one inch in diameter and a few inches long (you may use a test-tube with the bottom removed[1]), a cork that fits inside the glass tube, a heavy piece of wire, a beaker of water (Fig. 284).

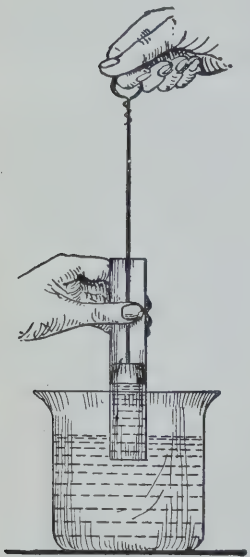


Fig. 284. What pushes the water up into the glass tube as the piston is raised?

Method.—The cork should exactly fit the piece of glass tubing. If the cork is a little too small for the tube, wrap string around it. Keep the small end of the cork upward. Make a handle on the cork by pushing a piece of wire about one foot long through the middle of the cork until the bottom end, bent in the form of a hook, sinks into the cork. (Make a hole through the cork for the wire with a small nail.) Now push the wire up through the glass tube. Make a loop on the end of the wire large enough to insert a finger. Wet the cork and draw it up into the glass tube as shown in the figure. If a test-tube is used, turn the blown end upward. Place the lower end of the glass tube a short distance under water in a beaker and, while holding the tube in this position with one hand, draw the wire upward to force the cork to rise in the glass tube.

NOTE.—This apparatus is similar to a lift pump in that the glass tube takes the place of the cylinder of the pump, the cork serves as a piston, and the wire acts as a piston rod.

Observation.—Does the water rise in the tube as the cork piston is raised?

Conclusions.—(1) Air presses downward, on the cork and on the water in the dish. When you pull the cork piston upward, what pressure downward upon it do you have to overcome? (2) When the downward pressure upon the water underneath the cork piston is removed by lifting up the cork, what pressure forces the water to follow the cork piston up the glass

[1]To open the bottom of the tube insert a stopper fitted with a tube. Heat the bottom, and, when it becomes soft, blow air into it until it bursts. Enlarge the hole with the end of a file while the glass is still soft.

tube or cylinder (Figs. 284 and 285)? (3) Does water rise up through this glass tube for the same reason that it rises up through a straw by suction when you are drinking a glass of lemonade?

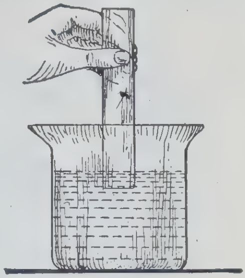


Fig. 285. Why does water not rise up through this tube?

Experiment II

Object.—To discover why water flows up into the cylinder of a lift pump.

Apparatus.—A glass model of a lift pump, a beaker of water (Fig. 286).

Method.—Push the piston of the pump as far down as it will go, lower the end of the pump a short distance down into a beaker of water, and lift the piston by pulling upward on the glass piston rod. Lower the piston again and repeat until water rises up to the piston and follows it up the glass cylinder of the pump. Continue to move the piston up and down till water flows from the pump. Watch the action of the valves and try to discover their use.

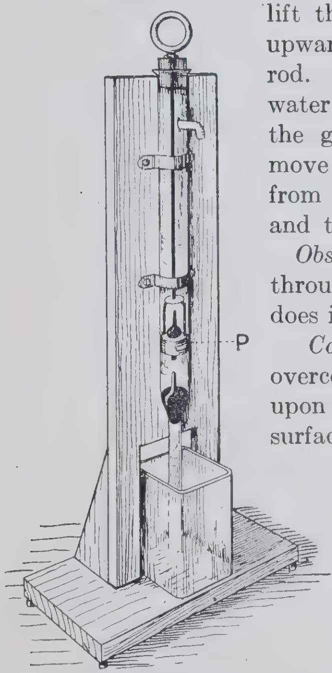


Fig. 286. Model of a lift pump. P, Piston. Compare this pump with the one shown in Figure 287. Why does water run up into the cylinder below the piston when the piston is raised?

Observations.—(1) Does water "flow up hill" through the pump following the piston? (2) How does it get up above the piston?

Conclusions.—(1) When the piston is raised, overcoming the downward pressure of the air upon it and thus removing the pressure from the surface of the water immediately below the piston, what forces the water to follow the piston upward? (2) Water finally flows up through the valve in the piston. When the piston is then raised, what do you have to lift besides the piston itself and the air above it? (3) Why do we therefore call this a "lift" pump?

Why does water rise in a lift pump?—Every lift pump has a piston, which is moved up and down in a cylinder by means of a piston rod. When the piston is raised, it lifts the air, or air and water, above it,

thereby reducing the downward pressure upon the water below it (Fig. 287). The pressure of air upon the surface of the water outside the pump is then greater than that upon the water inside and thus forces water to rise towards the piston inside the pump.

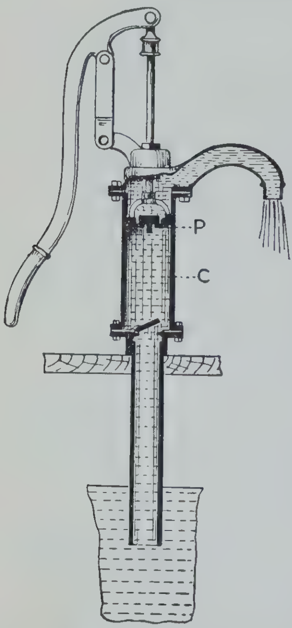


Fig. 287. Cistern pump. As the handle of the pump is pushed down, the piston (P) is pulled up. This lifts the water above it, causing it to flow out of the spout. Notice the valve resting in the middle of the piston. While the piston is being raised, this valve is held down by the weight of water and air above it. This prevents the water and air above the piston from running down into the cylinder (C). As the piston rises, will it therefore prevent air from pressing down upon the water below it in the cylinder? What forces the water to rise into the cylinder when the piston is raised, lifting the air above it?

Just as suction by the mouth makes the downward pressure of the air within a glass tube less than the pressure of the air on the surface of the water outside the tube, so the piston of a pump, on moving upward, reduces the downward pressure of air upon the surface of the water within the pump. This allows the greater air pressure outside the pump to force down the water sufficiently to send it up the tube of the pump.

A pressure of one pound per square inch is sufficient to force water up about two feet in a pump. Since the pressure of the air at the surface of the earth is about fifteen pounds per square inch, it will force water up to a height of about thirty feet in a pump or other tube. How far, therefore, may the cylinder of a pump be placed above the level of the water in a well (Fig. 288)?

When the cylinder of a pump is placed below the surface of the water in a well, air pressure is not necessary to make water rise in a lift pump. In this case the water is simply lifted up from the well by the piston. But in all cases where the

cylinder of the pump is placed above the water level in a well, air pressure forces the water up to the cylinder.

REVIEW

(1) Describe an experiment to show that air pressure forces water up to the cylinder in a lift pump. (2) What resistance must be overcome when the piston of a pump is raised? If you have an opportunity, grasp the piston rod of a pump and try to lift it. Why is it very difficult to lift? Examine the handle to see whether it helps to make pumping easy. (3) Why would it be impossible to pump water if the valve in the piston of a pump leaked badly? (4) Many years ago the Duke of Tuscany dug a deep well and discovered that the water would not rise in his pump more than a distance of about thirty feet. Can you suggest why it would not rise any higher? (5) Could the piston of a pump be placed at any distance above the surface of the water in a well? (6) What two important uses of air pressure have we found in this chapter?

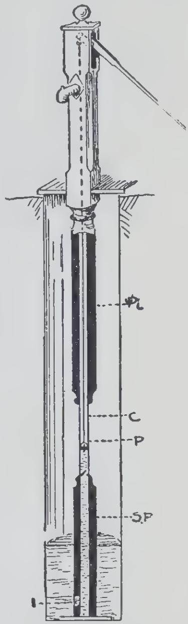


Fig. 288. Pump in well. C, Cylinder. P, Piston. SP, Wooden suction pipe. Pi, wooden pipe leading from cylinder to top of well. I, Opening to allow water to enter the pump. Would the pump shown in Figure 287 be satisfactory for winter use in a well placed outside? Give two reasons for placing the cylinder some distance down in deep wells.

III. THE BAROMETER

A very simple instrument called a barometer can be made to show air pressure. Not only will it demonstrate that air exerts pressure, but it will show also whether the pressure of the air always remains the same.

Experiment

Object.—To make and set up a barometer.

Apparatus.—A straight heavy glass tube called a barometer tube, about three feet long and closed at one end; clean, *dry* mercury, a small mortar, a tall stand fitted with two clamps, a *wide* shallow dish, a thistle-tube or funnel, a short length of rubber tube (Fig. 289).

Method.—Fill the small mortar to a depth of at least one inch with mercury. Support the long glass tube by the stand and clamps in an upright position, open end upward, over the flat dish. The dish is intended to catch any mercury that may spill. Carefully pour mercury into the tube until it is completely filled. When the barometer tube is full,

work the air bubbles off the sides with a small loop or a tuft of cotton on the end of a long piece of *iron* (stove-pipe) wire. Then wrap a cloth around the rubber tube and slowly work the rubber off the end of the barometer tube. The mercury that spills will be caught by the cloth. Slide it down the tube into the flat dish.

Loosen the clamps around the tube and remove both the tube and the flat dish from the stand. Place the mortar, partly filled with mercury, in the flat dish. Now grip the tube near the top end with one hand and place one finger firmly over the open end of the tube, being careful to see that no air remains between your finger and the mercury. Grasp the tube with the other hand near the bottom. Invert the tube, placing the end covered by the finger well down into the mercury in the mortar. Then remove the finger. Now, holding the mouth of the tube against the bottom of the mortar, and keeping the tube upright, very carefully lift the mortar out of the flat dish and place it on the stand. Support the tube in an upright position by the clamps. You have now constructed a simple *barometer*. Using a long ruler, measure the distance between the level of the mercury in the mortar and the level of the mercury in the glass tube.

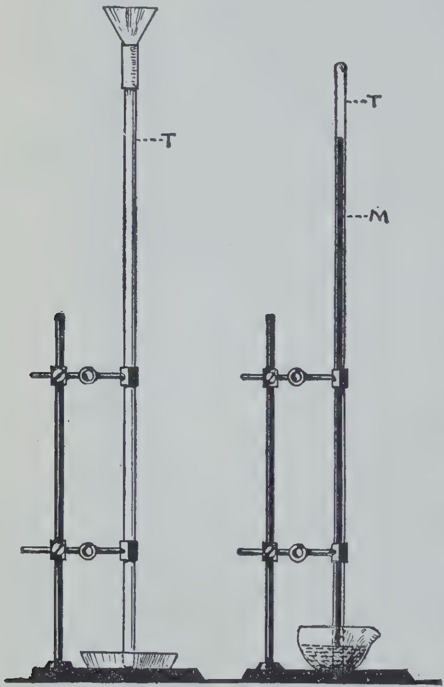


Fig. 289. T, Glass tube about thirty-five inches long, open at one end. M, Mercury. Why does the mercury remain up in the glass tube although the lower end of the tube is open? Why does the mercury not remain up to the top of the tube?

Observations.—(1) Does all of the mercury run out of the tube when the finger is removed from the open end? (2) If you succeeded in avoiding air bubbles, what is left in the upper part of the tube? (3) How many inches above the level of the mercury in the mortar is the top of the mercury in the tube?

Conclusions.—(1) What must be pressing down upon the mercury in the mortar to hold the column of mercury up in the barometer tube? (2) Is there any air within the top part of the tube to press down upon

the mercury? (3) Why does some of the mercury run out of the tube when the finger is removed? (4) Is the pressure of the air sufficient to hold up a column of mercury the full length of the glass tube? If not, what is the length of the column of mercury that it will support? The pressure of this column of mercury just balances the pressure of the air upon the surface of the mercury in the mortar.

Practical Exercise

Make a chart of two columns. In one column put the date of each day for a period of one month. In the other column write, day by day, the height in inches or millimetres of the mercury in the barometer. Measure it at the same time each day. By making these records you will be able to discover whether air pressure varies from time to time.

Fig. 290. Why does the height of the mercury in the narrow tube decrease when the air is pumped out of the large bell-jar covering it?

Why the mercury remains in a barometer.—Were it not for the pressure of the air on the surface of the mercury in the mortar, all the mercury would run down and out of the barometer tube when it is inverted in the mercury. Air pressure is sufficient to hold the mercury up many inches. Does the height to which the mercury is forced up or held in the tube vary from time to time? If so, it will indicate that the pressure of the air varies also.

No air can enter the barometer tube to fill the space left at the top when the mercury lowers. A space such as this, which has nothing in it, is called a *vacuum*. What would happen if air were admitted into this vacuum?

Review

(1) How would you make a simple barometer? (2) Why does mercury stand part way up a barometer tube? (3) How could you find out whether air pressure varies from time to time? (4) How could you create a vacuum? (5) If a large bell-jar is placed over the top of a barometer on an air pump (Fig. 290), and the air pumped out of the bell-jar, the mercury in the barometer falls to a lower level. Explain.

CHAPTER XXXVIII

FIRE

(1) When you wish a fire to burn up quickly, do you open or close the opening into the bottom of the fire? Why? (2) Why does fuel take longer to burn when the draughts are closed in a stove or furnace? (3) What becomes of coal or wood when it burns?

To us the making of a fire is a very simple matter. A little kindling, made by splitting up finely a few pieces of dry wood, and a match are all that are required. Had we lived a century or so ago, when we could have obtained no matches, what should we have done? No doubt we should then have used a piece of steel, a flint, and a little tinder. When a piece of flint, which is hard rock, is struck by a piece of steel, sparks are made. Have you ridden behind a horse after dark, and noticed the sparks which were formed when the shoe of the horse struck against a stone? In modern pocket lighters, to make sparks a roughened steel wheel is rubbed against a substance like flint (Fig. 291). These sparks set fire to gasoline, in a wick, which replaces the tinder of former days. Our forefathers directed the flying sparks from a steel and flint into a little dry tinder, usually made of partly burned linen, and thus ignited it (Fig. 292). From the burning tinder they could easily ignite the kindling for their fires.

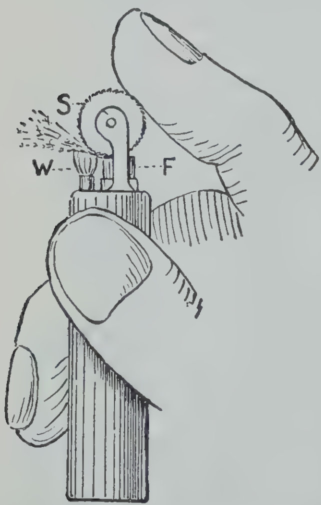


Fig. 291. Modern use of "flint and steel" to light gasoline. S, Steel. F, Flint. W, Wick.

We are told that long ago, when the use of the flint was not generally known, a tribe would keep one fire burning night and day. From this fire the people would carry burning coals or torches to light their own fires.

But, even to-day, are a match and a little kindling really all that are required to make a fire burn? Perhaps you would like to discover the answer to this question yourself.

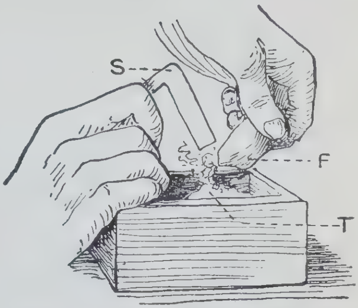


Fig. 292. Starting a fire by means of a flint-and-steel. When the flint (F) was struck by the steel (S), sparks flew from the flint into the dry tinder (T) placed near by. Find the flint and steel wheel in a modern gas lighter.

Experiment I

Object.—To find out whether a match and some kindling are all that are necessary to kindle a fire. (First method.)

Apparatus.—A quart sealer, a board just large enough to cover the sealer, a thin dry splinter about six inches long, matches, water.

Method (*Part A*).—In the centre of one side of the piece of board make a slit with a knife. Fit one end of the splinter into the slit. Ignite the splinter with a match and place it in the jar as shown in the diagram (Fig. 293).

Observation.—Does the splinter continue to burn until it is completely consumed by the fire?

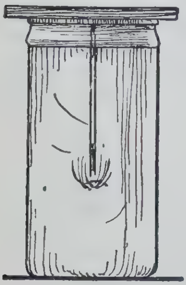


Fig. 293. What is in the jar besides the burning splinter?

Method (*Part B*).—When burning ceases, gently remove the board, pull out the splinter, and replace the board on the sealer as soon as possible. Holding the splinter in one hand, reignite it and thrust it down into the jar.

Observation.—Does the splinter cease burning at once?

Method (*Part C*).—Now fill the jar with water, forcing out the air that it contains. Then empty out the water, allowing fresh air to fill the jar. Hold the splinter with a pair of tongs or pincers or a piece of wire, reignite it, and again thrust it into the jar.

Observation.—Does it continue to burn this time?

Conclusions.—(1) What gas is in the sealer before the splinter is placed in it the first time? (2) The burning splinter soon goes out when enclosed

along with a small amount of air within a sealer. It refuses to burn when reignited and again placed in the sealer. But, when fresh air enters the open jar, the splinter continues to burn. What is therefore necessary, besides a match and a splinter (or some kindling), to make a fire burn?

Experiment II

Object.—To show that air is needed to support burning. (A second method.)

Apparatus.—Two quart sealers, a glass top for one sealer, two candles.

Method.—Place a short piece of candle on the bottom of each sealer and, using a splinter, or a match with a wire handle, ignite the candles. See that each candle burns up brightly. Then place a cover over one sealer so that no more air can enter it (Fig. 294).

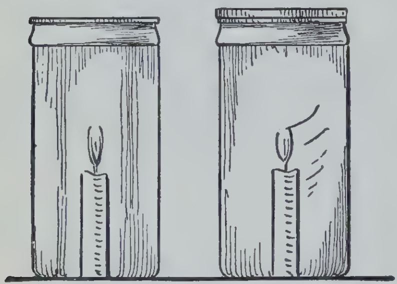


Fig. 294. In which sealer will the candle continue to burn? Why?

Observation.—How long will each candle continue to burn?

Conclusion.—Is air necessary to support burning?

Experiment III

Object.—To show that air is needed to support burning. (A third method.)

Apparatus.—A quart sealer with a glass cover, three candles, water, and matches (Fig. 295).

Method.—Place a short piece of candle in the sealer and ignite it. Cover the sealer with the glass top. After a minute ignite a second candle and lower it by a piece of wire into the sealer containing stale air. (Stale air is air in which a fire has been burning until it will burn no longer.) Then fill the jar with water to force out all the stale air and empty the water out to allow fresh air to enter. Finally, lower a burning candle by a piece of wire into the open jar.

Observations.—(1) Describe what happens when the cover is placed over the jar containing the burning candle. (2) Will the candle burn when lowered into the jar containing stale air? (3) Does the candle continue to burn when placed in an open sealer filled with fresh air?

Conclusions.—(1) Is air necessary to support burning? (2) Can the air enclosed in a small space support burning indefinitely, that is, as long as the candle lasts?

Air supports burning.—When a smouldering cloth or stick is placed near the opening in front of a stove, the

smoke from it is drawn into the fire. The movement of the smoke tells us that a current of air must be entering the fire.

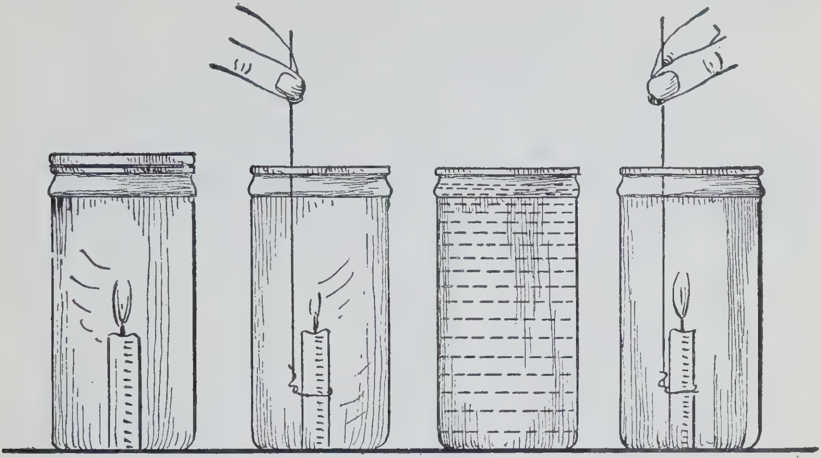


Fig. 295. This diagram illustrates the four steps to be taken in Experiment III on page 352.

Just *why* this is necessary is suggested by the results of our experiments. Fire cannot continue to burn unless it is supplied with air that has not been made stale by burning. This current of fresh air is entering the stove and supporting the burning of the fuel. As the air becomes spoiled with burning, it escapes up the chimney.

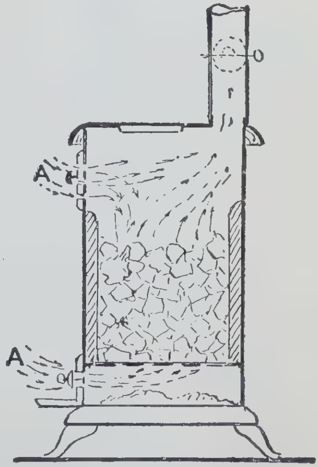


Fig. 296. Stove showing entry of air (A) that supports burning.

Can you now suggest why a fire burns longer when the draughts in front of the stove are partly closed than when they are wide open? Since fuel requires air in order to burn, the rate at which it burns is determined by the amount of air entering the fire. When, by partly closing the draughts, little air is admitted, the rate of burning is slow, and the fuel is there-

fore consumed much less rapidly than when the draughts are opened wide.

Questions for Discussion

(1) Why should a blanket, a coat, a rug, or some similar object be wrapped around a person whose clothes have caught fire? (2) Why must a wood fire be arranged loosely in order to burn well? (3) Why are there holes in the base of a lantern or lamp? (4) Why will a lamp not burn if the top of the chimney is closed? (5) Why will a fire burn less brightly when the draught of the furnace or stove is closed? (6) What would be the result of excluding air completely from the fire in a stove?

Review

(1) Show by an experiment that air is necessary for burning. (2) How can you show that air enclosed in a small space will not support burning indefinitely?

CHAPTER XXXIX

NATURE OF AIR. WHAT IS BURNING?

When a lighted candle is enclosed in a sealer, it soon goes out. We conclude that air is needed to support burning. Let us now enquire whether all the air within the sealer is useful for this purpose.

Experiment

Object.—To discover whether all of a sample of air supports burning.

Apparatus.—A quart sealer with its glass top and rubber ring (a two-quart sealer would be better), a piece of candle about three inches long, a second candle or a splinter, a flat-bottomed dish containing limewater (see page 369) at least two inches in depth (Fig. 297).

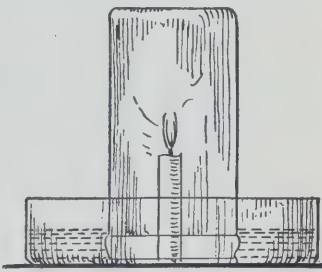


Fig. 297. Why does the limewater not enter the jar when first it is inverted and lowered into the water? What will force water to rise in the jar when the candle uses up some of the air within it?

Method.—Heat the bottom of the candle till it begins to melt. Then press it against the middle of the inside of the glass cover and hold it there till it sticks. Fit the rubber ring on the sealer or on the cover. Set the glass cover on the bottom of the dish so that the top of the candle is a little above the surface of the limewater. Cut the candle wick short so that its flame will be small. Light it. Invert the sealer filled with ordinary air over it, and push the mouth of the sealer down until it fits tightly on the cover. Hold it in place firmly to prevent the escape of heated air. Allow the apparatus to stand until it is cool. Keeping the mouth of the sealer under water, loosen the cover. After a moment close it tightly again and invert the sealer. Light the second candle or splinter and thrust it into this sealer of air in which a candle has burned.

Observations.—(1) Does this second candle soon go out? (2) Does the water rise in the jar when the gas left in it becomes cool again? (3) If water rises into the sealer, does it show that some of the air has been used up? (4) Does the rest of the air in the jar support burning?

Conclusion.—Is the burning of the candle supported by all of the air or by only part of it?

NOTE.—Part of the air in the jar unites with the candle to form a gas. This gas dissolves in the limewater and so is removed from the jar. It therefore does not prevent water from entering the jar to take the place of the air that has been used up.

Experiment II

NOTE.—By using phosphorus instead of a candle, as in the last experiment, we can obtain a more accurate idea of how much of the air is used in burning. Phosphorus, however, is very dangerous to handle because it will ignite very easily and burn violently in air.[1] When simply left exposed to air, it will ignite. To keep air from it phosphorus must be stored under water. If there is danger of frost in your school, the phosphorus must be stored in such a way that freezing will not break the bottle. (See Appendix, Sec. 25). Only a very small amount of phosphorus is needed in a school. One-quarter of an ounce will be sufficient for one class. No one but the teacher should perform experiments using phorphorus. Handle it with forceps and always cut it under water.

Apparatus.—A cork or a piece of wood about an inch and a half across, a piece of tin to cover the cork or wood, a quart sealer, a flat dish containing water about one to two inches in depth, a piece of phosphorus about the size of a small pea, a piece of cardboard, a splinter (Fig. 298).

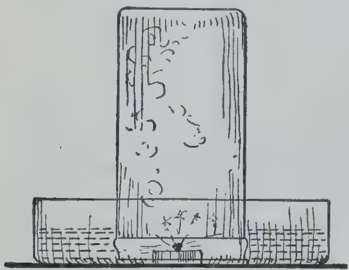


Fig. 298. Why does water enter the sealer after the phosphorus has been burning for some time? How far does it rise in the sealer? What fraction of the air is used up in burning?

Method.—Cover the cork or piece of wood with the piece of tin and float it on the water in the flat dish. A floating tin lid smaller than the mouth of the sealer may be used instead of the cork and piece of tin. Ignite the phosphorus with a match and quickly invert the sealer over it. Allow the apparatus to stand until the jar becomes perfectly clear. Measure the height of the water in the sealer. Then slip the piece of cardboard under the sealer, press it upward to close the mouth, and turn the jar right side up. Light the splinter and thrust it into the jar.

Observations.—(1) Is there any smoke (we call it fumes) formed in the sealer as the phosphorus burns? (2) What fraction of the jar becomes filled with water as the fumes dissolve? (3) Does the remaining air support burning?

[1]In case of burns, immediately immerse the part in water. Then bathe with a weak solution of picric acid.

Conclusions.—(1) How much of the air seems to be used up to support burning? (2) How do you know?

NOTE.—The white fumes formed when the phosphorus unites with part of the air in burning dissolve in the water. In this way, the part of the air used up in burning goes into the water in the dish and allows water to come in and take its place.

How much of the air supports burning?—When the experiment recorded above is performed, we find that water rises about one-fifth of the way up the sealer. It takes the place of the part of the air that supports burning. Only about one-fifth (approximately twenty-one per cent) of the air, therefore, supports burning. The part of the air that supports burning is called **oxygen.** Without oxygen in the air we could have no coal and wood fires in our furnaces and stoves to keep us warm and to cook our food.

The rest of the air.—The part of the air that does not support burning or combustion is chiefly **nitrogen.** We have found that about one-fifth of the air is oxygen. Nitrogen, therefore, makes up nearly four-fifths of the air. It resembles oxygen in that it is invisible and has no odor or taste, but it takes no part in burning and so is a far less active gas than oxygen.

Besides oxygen and nitrogen, air contains about one per cent of other gases. With one of these gases we are already familiar. Water placed in a kettle on a hot stove for an houı gradually disappears. What becomes of the water? After a rain the ground quickly dries in the hot sun. What becomes of some of the moisture? We all know that water changes into an invisible gas called water vapor and escapes into the air. From this water vapor or gas, which forms but a small percentage of air, we get our rain and snow. Of the other gases making up the rest of this one per cent of air we shall learn later.

What is burning?—When a body burns, it unites with oxygen of the air. A ton of coal, for example, unites with

about two tons of oxygen. (Since air is only about one-fifth oxygen, how many tons of air will pass through the furnace to burn one ton of coal?) The substances formed in the burning contain the oxygen used up from the air. These new substances may or may not be visible. When a candle burns, invisible gases are formed, and the candle, therefore, seems to disappear. By proper methods, however, these substances may be collected. Because the substances formed in burning contain oxygen, they are usually called *oxides*.

Review Outline

(1) Describe an experiment to show that only part of the air supports combustion or burning. How much of the air does support burning? (2) Name the two gases of which air is chiefly composed. Which supports burning? (3) What is burning?

CHAPTER XL

OXYGEN, THE GAS THAT SUPPORTS BURNING. ITS RELATION TO RUSTING

The oxygen of the air is greatly diluted[1] by the nitrogen with which it is mixed. Its activity is accordingly weakened. To learn exactly what oxygen can do and what it is like we must obtain some of it that is not diluted. How can we prepare pure oxygen? We know that there is plenty of it in the air, but the nitrogen and the oxygen of the air are invisible gases, and there is no easy method of separating them. It is therefore difficult to get pure oxygen from the air. It can, however, be obtained from certain substances which contain it. One of these substances is called *potassium chlorate.*

Experiment

Object.—To prepare pure oxygen gas.

Apparatus.—A test-tube fitted with a one-holed stopper, a piece of glass tubing about eighteen inches long, a flat pan or dish, a small stand, several bottles of about eight ounces or 250 cubic centimetres capacity, pieces of glass or cardboard to cover the mouths of the bottles, three rubber stoppers, water, potassium chlorate, manganese dioxide.

Method.—Put some *potassium chlorate* in the test-tube to a depth of about an inch and a half. Add about one-third the bulk of *manganese dioxide.* Shake the test-tube until the two substances are thoroughly mixed. Bend the glass tubing[2] into the shape shown in the diagram (Fig. 299) and fit it into the one-holed stopper. Fit the stopper into the test-tube and mount the tube on the small stand placing the lower end of the glass tube under water in the pan or dish. (A flat dish used for collecting gases is called a "pneumatic trough.") Fill one of the collecting bottles with water and place a piece of glass or cardboard over

[1]"Diluted" means "made weaker." If you add water to lemonade or tea, you dilute it or make it weaker.

[2]For the method of bending glass see Appendix, Sec. 11.

its mouth. Then, holding the cover in place with one hand, invert the bottle and lower it into the pan of water directly above the end of the glass tube. Remove the glass or cardboard after the mouth of the bottle is below the surface of the water in the pneumatic trough. Rest the mouth of the bottle on a suitable support, such as three rubber stoppers, under the water so as to hold the bottle in an upright position. Gently heat the mixture in the test-tube.

Observations.—(1) Is any gas being formed? How do you know? (2) What becomes of the gas? (3) Is enough gas formed to fill the bottle?

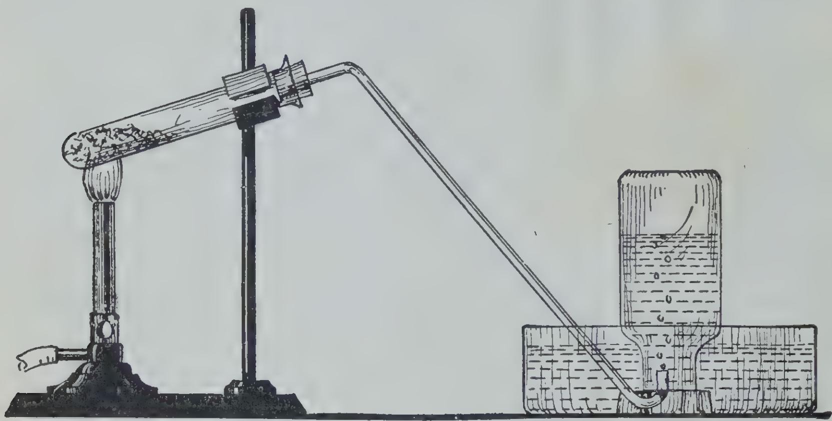


Fig. 299. Apparatus showing how oxygen may be obtained from a mixture of potassium chlorate and manganese dioxide. Why does the water go out of the bottle as the oxygen collects at the top? Why does water stay up in the bottle at first? From which substance in the test-tube is the oxygen obtained? What is the purpose of the other substance? Could we collect oxygen over water if it dissolved rapidly?

(4) The bottle is larger than the test-tube. Where did this large amount of gas come from?

Conclusion.—When potassium chlorate is heated with manganese dioxide, does it give off a large volume of gas? (This gas is oxygen, the same gas that you find in air.)

Note.—It is possible to obtain oxygen from potassium chlorate without the aid of manganese dioxide, but to do so requires much more heat than is necessary when manganese dioxide is used.

When the bottle has been filled with oxygen, place a small piece of glass or cardboard over its mouth, invert it, and place it on the desk. Leave the cover on it. Collect six bottles of oxygen in the same way. When sufficient gas has been collected or when no more gas will form, either lift the glass tube out of the water or remove the stopper from the

test-tube. This should be done before heating is discontinued. If it is not done, the gas within the test-tube will contract as it cools, making the pressure inside less than the pressure of the air outside on the surface of the water in the pan. What will happen? Why?

Experiments with oxygen gas to find out what it will do.—Now let us perform a few experiments with the oxygen gas that we have collected in the bottles. By these experiments we may find out what oxygen is like when it is pure and not diluted with nitrogen gas as it is in air.

Experiment I

Object.—To find out whether oxygen supports the burning of a splinter.

Apparatus.—A bottle of oxygen gas, a glowing splinter.

Method.—Ignite the splinter and let it blaze. Then blow out the flame, leaving the end of the splinter glowing. Thrust the glowing splinter into the bottle of oxygen that you have prepared.

Observations.—(1) Does the splinter burn in oxygen? (2) Does it burn better in pure oxygen than in the air, which is oxygen diluted with nitrogen and other gases?

Conclusion.—Does pure oxygen support burning of a splinter very well?

Experiment II

Object.—To find how oxygen and sulphur act together.

Apparatus.—A deflagrating spoon,[1] a bottle of oxygen gas, a burner or alcohol lamp. Examine the diagram (Fig. 300) to see two types of deflagrating spoons that may be used.

Method.—Put a little sulphur in the deflagrating spoon and ignite it by holding the spoon in the flame of the burner or alcohol lamp. Notice how well it burns in air, which is in reality oxygen greatly diluted with other gases. Then lower it into the bottle of oxygen gas (Fig. 300). After burning ceases, carefully smell the contents of the bottle.

Observations.—(1) Does the sulphur burn more brightly in oxygen than in air? Compare the appearance of the flame in each case. (2) Does some of the sulphur disappear when it burns or unites with the oxygen? (3) The gas formed when sulphur burns with oxygen is a sulphur *oxide* called sulphur dioxide. (4) Does the sulphur dioxide seem different from the oxygen and the sulphur which united to form it?

[1]A piece of chalk hollowed out at one end and attached to a piece of wire makes a good spoon in which to burn substances.

Conclusions.—(1) What can oxygen do with sulphur? (2) Is it more active in pure than in dilute form? How did you show this in the above experiment? (3) When sulphur burns, does it unite with oxygen to form a substance quite different from both oxygen and sulphur? How does it differ from each of them?

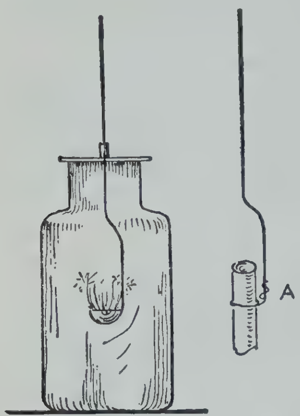


Fig. 300. A, Piece of chalk hollowed at one end and attached to a wire handle. This type of spoon may be used in place of the metal one shown in the bottle. What is taking place within the bottle?

Experiment III

Object.—To find out whether oxygen dissolves in water.

Apparatus.—A shallow dish of water, a bottle of oxygen (Fig. 301).

Method.—Invert the bottle of oxygen gas over a little water in the shallow dish. When the mouth of the bottle is below the surface of the water in the dish, remove the cover from the bottle. Allow the apparatus to stand for two or three days.

Observation.—Does the water rise in the bottle? If so, how far?

Conclusions.—(1) Is oxygen soluble to some extent in water? (2) Would you expect any oxygen of the air to dissolve in rivers, lakes, oceans, and other waters of the earth?

Experiment IV

Object.—To find out whether oxygen will support the burning of iron.

Apparatus.—A piece of soft picture wire made of several strands, a little sulphur, a bottle of oxygen gas containing about an inch of water (Fig. 302).

Method.—Heat the end of the piece of picture wire until it is quite hot. Then dip it into a little sulphur. Ignite the sulphur that adheres to the hot wire and quickly lower into the bottle of oxygen gas the end of the wire on which the sulphur is burning.

Note.—The sulphur is used to ignite the iron just as a match is used to ignite kindling.

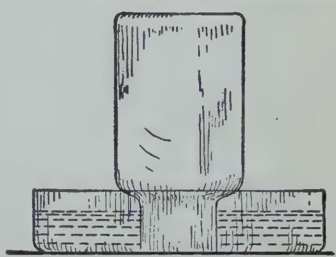


Fig. 301. How shall we know whether the oxygen within this bottle is soluble in water?

Observations.—Does the iron burn in air? Does it burn in pure oxygen giving out many bright sparks? What is formed in the bottle?

Conclusions.—(1) Will oxygen support the burning of substances like iron that will not burn in air as sulphur does? (2) Does oxygen unite with iron to form an iron-oxygen substance (*iron oxide*) different from the iron and oxygen of which it is composed? Crumble the oxide with a hammer.

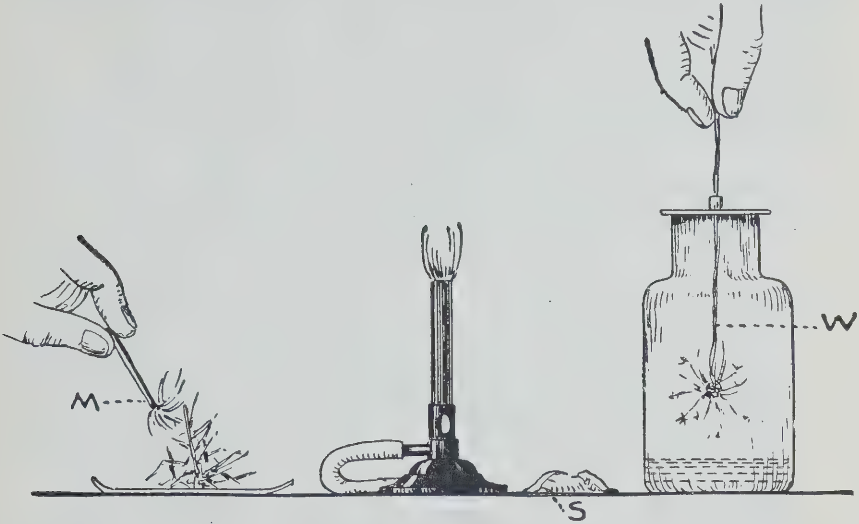


Fig. 302. M, Match. S, Sulphur. W, Iron picture wire. A burning match will heat kindling to a temperature at which it will burn. What will the burning sulphur on the end of the wire do? What would hot iron oxide do if it fell from the wire on to the bottom of the glass bottle? Why is water placed in the bottom of the bottle?

Experiment V

Object.—To find whether pure oxygen will support the burning of a candle.

Apparatus.—A short piece of candle, a piece of wire about eight or ten inches long, a bottle of oxygen gas.

Method.—Lower the candle, by means of the piece of wire, into the bottle of oxygen gas (Fig. 303).

Observation.—Does the candle burn more brightly in oxygen than in air?

Conclusion.—Is the burning of a candle supported better by pure oxygen than by air?

What can oxygen do?—We have already learned that, when a substance burns in air, the oxygen is the only part of the air that supports the burning. When the oxygen of the air is used up, therefore, burning ceases. In pure oxygen,

however, burning may last much longer than in air because the supply of oxygen is nearly five times as great in pure oxygen as in an equal volume of air. Moreover the burning is much more rapid because the oxygen is not diluted by any inactive gases.

When sulphur, a splinter, iron, a candle, or any other substance burns in oxygen, it unites with the oxygen. Sulphur unites with oxygen to form a colorless gas with a suffocating odor. This gas, made of sulphur and oxygen, is called *sulphur dioxide.* Does it form when sulphur burns in air? Why? In the same way, when iron burns in oxygen, it unites with it to form a substance made of iron and oxygen which we call *iron oxide.* Similarly oxygen unites with a great many substances which burn in it, forming *oxides.*

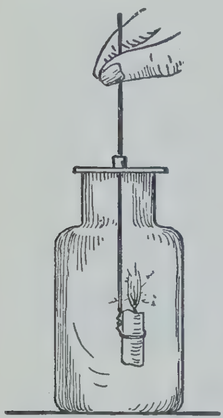


Fig. 303. A candle burning in pure oxygen gas.

Oxygen is slightly soluble in water. Though very little of a bottle of oxygen seems to dissolve in water, the total amount of oxygen of the air that dissolves in the waters of the earth is considerable. Fish and other animals that breathe under water depend upon the oxygen that dissolves in the water to supply their need.

How abundant is oxygen?—Surrounding the earth, as we have learned, is a great ocean of air. Over one-fifth of this is oxygen. We have already seen that iron oxide is made when iron unites with oxygen. In some places there are whole ranges of hills which are composed chiefly of iron oxide. The rocks and soils of the earth consist partly of oxides of iron and partly of other substances. Of the solid part of the earth about one-half is oxygen. Covering nearly five-sevenths of the earth we find water in one form or another. It, too, is an oxide. It is hard for us to realize how

much water there is upon the earth. Can you imagine how long it would take to dip out all the water from a pond with a gallon pail? A pond is but a drop compared with the water in any one of our great lakes or streams. How great must be the volume of water in our vast oceans! Every gallon of water weighs about ten pounds, and over eight pounds of this is oxygen! What an enormous amount of oxygen there must be in all the waters of the earth! Thus we see that in air, in the earth, and in water, oxygen is very abundant.

Air. Its relation to rusting.—Any material, such as a piece of wood, burns by uniting *rapidly* with the oxygen of the air. In so doing it gives off both heat and light. It is possible, however, that some substances or materials may unite with the oxygen of the air so very slowly that we see no light and feel no heat.

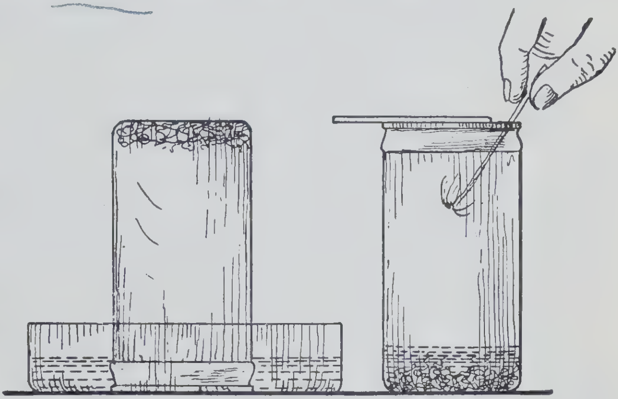


Fig. 304. Why does no water enter the sealer when it is first inverted over the water? Air is but slightly soluble in water. Why, then, does the water rise so far up the sealer in a day or two? What is the purpose of thrusting the lighted splinter into the sealer? Why does the splinter go out?

Experiment

Object.—To discover whether the oxygen of the air sometimes unites slowly with materials.

Apparatus.—A little steel wool (a few iron filings will serve as well), a quart sealer, a shallow dish, water, a piece of glass to cover the sealer.

Method.—Pack some steel wool (thin shavings of iron) into the bottom of the quart sealer and wet it with a little water. Set the sealer, mouth downwards, in the shallow dish containing about an inch of water (Fig. 304). Allow the sealer to remain in the water for about two days. Then place the piece of glass under the mouth of the sealer, hold it in place

firmly, and invert the sealer. Retain in the sealer all the water that has risen into it. Place the sealer on the desk and thrust a lighted splinter into it. (If filings are used, wet the jar and stick them to the bottom and sides.)

Observations.—(1) Does the steel wool rust while in the sealer? (2) To what extent does water rise in the sealer? This will be shown by the amount of water that it contains. (3) Does the splinter continue to burn when thrust into the sealer? (4) Did you see any light or feel any heat when the iron was rusting?

Conclusions.—(1) Can you suggest an explanation for rusting, basing your answer upon the fact that about one-fifth of the air within the beaker is used up? (2) Why does the splinter cease burning? Does this suggest what has been taken from the air as the iron rusts?

Note.—Is iron the only metal that rusts or tarnishes? Examine pieces of old brass, copper, zinc, silver, and lead.

What is rusting?—When a piece of iron or other metal rusts, it unites with the oxygen of the air. It forms oxides in the same way that wood and sulphur do, but the union is much slower in the case of the metal than in the case of the wood and the sulphur. In rusting, heat is given off, but it is formed so slowly that we cannot feel it. No light is given out.

Oxidation.—The union of any substance with oxygen is called **oxidation.** Union with oxygen of the air (oxidation) is rapid when a splinter of wood, a candle, or a little sulphur burns. *Rapid* oxidation is called **combustion** or "burning." We can see the light and feel the heat that is given off when combustion takes place. On the other hand, oxidation is slow when iron or other metals rust.

Review Outline

(1) How would you prepare pure oxygen? Why do you not try to obtain it from the air? (2) Describe an experiment to show that oxygen supports burning. In this respect state how oxygen differs from air. When substances such as sulphur and iron burn, what is formed? (3) Is oxygen very soluble in water? State the importance of the solubility of oxygen in water. (4) Has oxygen any color or odor? Compare it in this respect with air. (5) How could you show that, when iron rusts, it unites with the oxygen of the air? (6) What is combustion? Rusting?

CHAPTER XLI

CARBON DIOXIDE

Have you ever wondered where the heat comes from which keeps our bodies warm? Just as a stove takes in air containing oxygen, which unites with the coal or wood within it to form heat, so we take into our bodies air containing oxygen, which unites with the food that we eat and produces heat.

Of the twenty-one per cent of oxygen in the air that we breathe, nearly five per cent is absorbed into the blood in the lungs with each breath. From the lungs, this oxygen is carried by the blood to all parts of the body. Within the body the oxygen unites with the food that has been digested.

In the last chapter we saw that, when a substance such as iron burns, it joins with oxygen, *producing heat* (*energy*) *and forming an oxide.* When food burns or unites with oxygen within our bodies, does it produce heat and energy and form an oxide?

We eat plants and animals for food. If we know what substances are in them, we shall understand with what the oxygen unites. Let us test some plant and animal substances.

I. EXPERIMENTS TO FIND ONE OF THE MAIN SUBSTANCES OF WHICH PLANTS AND ANIMALS ARE MADE

Experiment I

Object.—To find the main substance of which plants are made.

Apparatus.—A splinter of wood about six inches long, a burner, a piece of white paper.

Method.—Ignite the splinter of wood. Turn it with the flame uppermost until the fire slowly dies out. Then rub the charred part of the splinter on the piece of white paper.

Observations.—(1) What color is the mark made on the paper? (2) What is the charred wood like,—hard, soft, rough, smooth, light, dark?

Conclusion.—Does wood contain, hidden in it, the black substance which we call charcoal? This black substance is also called *carbon.*

Experiment II

Object.—To find what proportion of a splinter of wood is carbon.

Apparatus.—A test-tube, a test-tube holder, a burner, a few dry splinters of wood, a piece of white paper.

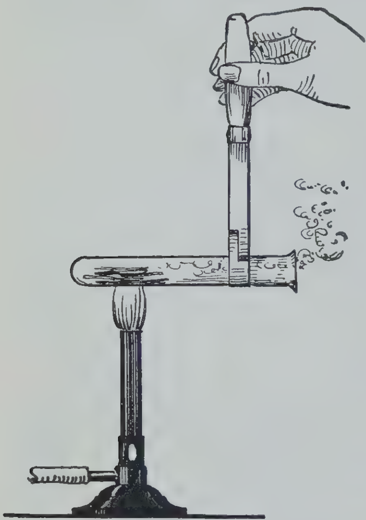


Fig. 305. When the test-tube is held horizontally, the gases that are driven off from the wood collect in it and prevent air from reaching the heated wood. What is the advantage of this?

Method.—Put the splinters in the bottom of the test-tube. Then with the test-tube holder hold the test-tube in a horizontal position over the burner (Fig. 305) and heat the wood strongly. After most of the smoke and gas ceases to escape from the test-tube, allow the contents to cool and then shake out the solid part that remains on to the piece of white paper. Rub a little of it on the paper. Powder a little of it between your thumb and first finger.

Observations.—(1) What is the appearance and nature of the solid? (2) Are the pieces of carbon nearly as large as the splinters that you put in the test-tube?

Conclusion.—Is there a considerable amount of carbon in the woody part of a plant? (Is there anything else in wood besides carbon?)

Experiment III

Object.—To find whether foods such as sugar, bread, and meat contain carbon.

Apparatus.—Three test-tubes, a test-tube holder, a burner, a little sugar, a piece of bread, a small piece of meat.

Method.—Heat each substance in a separate test-tube as in Experiment II but very slowly.

Observation.—What is the nature of the solid that remains in each test-tube after the heating is discontinued?

Conclusion.—Do bread, sugar (plants), and meat (animals) contain carbon?

We have now discovered that there is carbon in both plants and animals. Further experimenting would prove to us that nearly all plant and animal substances contain carbon. When we eat plants and animals and their products such as sugar, milk, and eggs, we therefore take carbon into our bodies.

II. CARBON AND OXYGEN

Foods that we eat and the oxygen that we breathe are carried by the blood to the muscles and other parts of our bodies. We naturally wish to know whether this carbon and oxygen may unite to form an oxide.

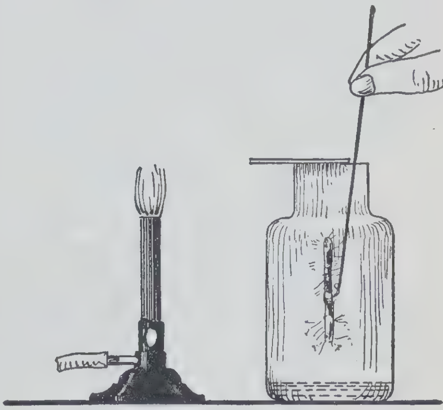


Fig. 306. Charcoal burning in pure oxygen. Would the charcoal burn if the bottle contained air? Why? When the charcoal burns, what is formed that causes the limewater to turn milky?

Experiment

Object.—To find out whether carbon will unite with oxygen to form an oxide.

Apparatus.—A bottle of oxygen gas, a piece of charcoal (you may use a piece of the charcoal prepared in Experiment II, page 368), a piece of fine wire about eight inches long, an alcohol lamp or a burner (Fig. 306).

Method.—Put about three or four tablespoonfuls of limewater[1] in the bottle of oxygen gas. Shake them together. Carefully attach one end of the wire to the piece of charcoal. Hold the charcoal over the burner until it glows and then lower it into the bottle of oxygen gas. After the charcoal has ceased to burn, shake the limewater up and down in the bottle again to find out whether the gas has been altered by the burning.

[1]*Limewater* may be prepared as follows. Fill a pint sealer about one-tenth full of lime (also called quicklime and calcium oxide) and add enough water nearly to fill the jar. Cover it tightly and shake thoroughly from time to time for a day. After any undissolved lime has settled, you may pour off the clear limewater whenever required. More water may be added to the jar from time to time as long as it contains any undissolved lime.

Observations.—(1) Does the charcoal burn more brightly in oxygen than in air? Why? (2) Does it gradually disappear as it burns? (3) Does the limewater turn milky (*a*) in the pure oxygen? (*b*) after the oxygen has united with the carbon?

Conclusions.—(1) Have you a reason for thinking that some of the carbon has united with the oxygen? (2) When carbon unites with oxygen, does it form a gas that turns limewater milky? This gas which turns limewater milky is an oxide of carbon called **carbon dioxide.** Does it form when wood and coal burn?

III. THE AIR THAT WE BREATHE OUT

Experiment

Object.—To find out whether the air that we breathe out is the same as it was when we breathed it in.

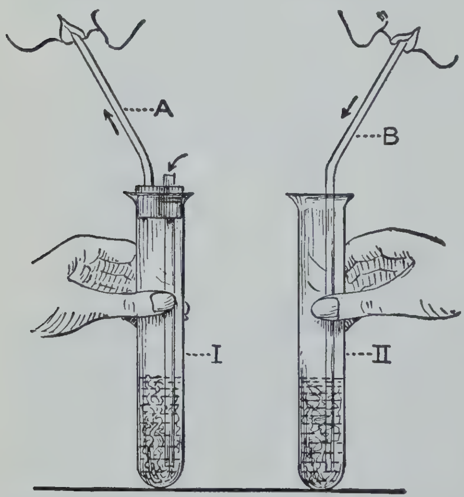


Fig. 307. Ordinary air is being bubbled through the limewater in the test-tube placed on the left-hand side of the diagram. Air from the lungs is being bubbled through the limewater in the other test-tube. How may we know which air contains the more carbon dioxide?

Apparatus.—Two large test-tubes, a two-holed stopper to fit one of them, three glass tubes as shown in Figure 307 (they need not be bent), sufficient clear limewater to fill the test-tubes about one-third full.

Method.—Set up the apparatus as shown in the diagram. Take a deep breath, drawing air slowly into the lungs through tube A. Hold it in the lungs for a time and then slowly breathe it out through tube B, keeping the lower end of the tube near the bottom of the limewater. Repeat this several times.

Observation.—The air that you breathed in bubbled through limewater in test-tube I and the air that you breathed out bubbled through limewater in test-tube II. How did it affect the limewater in test-tube I? In test-tube II?

Conclusions.—(1) Is the air that we breathe out the same as it was when we breathed it in? (2) What has been added to it?

Why do we find carbon dioxide in our breath?—When a piece of pure carbon such as charcoal is burned in a bottle of oxygen, heat and light are produced, and invisible carbon dioxide gas is given off. Similarly, the carbon hidden within plants may burn rapidly by uniting with the oxygen of the air to produce heat and light as well as carbon dioxide. What plants do we use for fuel? Similarly, also, the carbon contained in our foods (which are in reality plants and animals and their products) unites with the oxygen of the air which we breathe. While the union in this last case is slow, nevertheless heat, energy, and carbon dioxide are produced. The heat formed by this union makes our bodies warm. The rest of the energy produced enables us to do our work. The carbon dioxide formed by this union, however, cannot be made use of by the body. It is therefore carried by the blood to the lungs, where it escapes into the air that we breathe out. While ordinary fresh air contains but a trace of carbon dioxide (.04 per cent) the air that we breathe out from our lungs is about four per cent carbon dioxide. Thus the air breathed out contains nearly one hundred times as much carbon dioxide as the fresh air that we breathe in.

IV. FURTHER OBSERVATIONS UPON CARBON DIOXIDE

In order to learn more about carbon dioxide let us prepare several bottles of the gas so that we may experiment with it. We could prepare it by burning charcoal in pure oxygen within bottles. This method however would be slow. By the use of two substances, *marble* and *hydrochloric acid*, we can quickly prepare and collect any quantity that we need.

Experiment I

Object.—To prepare a quantity of carbon dioxide.

Apparatus.—A Florence flask or a large bottle, a two-holed stopper

to fit it, a thistle-tube, a piece of glass tubing, a flat dish, four bottles in which to collect the gas, hydrochloric (muriatic) acid,[1] marble or limestone.

Method.—Break the marble into pieces small enough to enter the flask. Carefully slide several of these pieces into the Florence flask. Then set up the apparatus as shown in the diagram (Fig. 308). Review the method of preparing oxygen (page 359) to refresh your memory regarding the method of collecting a gas over water. See that the end of the thistle-tube almost touches the bottom of the Florence flask. Pour water into the flask until it rises above the lower end of the thistle-tube. Then

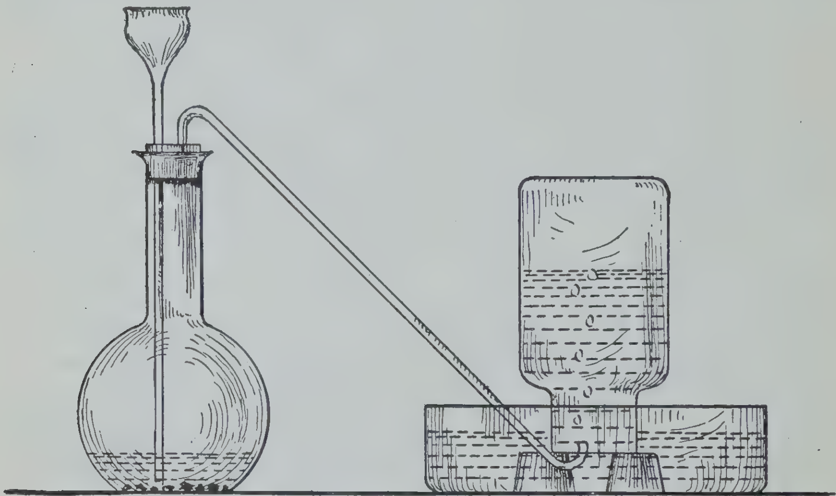


Fig. 308. The Florence flask contains hydrochloric acid and small pieces of marble. The carbon dioxide that is formed when these two substances are put together collects in the bottle and forces out the water which it contains.

add a little hydrochloric acid from time to time as required, and collect five bottles of gas. Discard the first bottle because it will contain air from the flask. Add a little limewater to one of the bottles of gas and shake well.

NOTE.—You will recall that limewater is the test for carbon dioxide. Carbon dioxide always turns it milky.

Observations.—(1) Does foaming or effervescing occur in the Florence flask? Why? (2) What is the color of the gas collected? Could you see it in air? (3) What is the action of the gas on limewater?

[1]Vinegar may be used instead of hydrochloric acid because it contains an acid. Egg shells, scale from the inside of a kettle, baking soda or washing soda may be used instead of marble or limestone.

Conclusion.—What is the gas collected? What can you use when you wish to prepare carbon dioxide in large quantities?

Experiment II

Object.—To find whether carbon dioxide supports burning.

Apparatus.—Two bottles of carbon dioxide gas, a splinter, a small piece of paper (Fig. 309).

Method.—Try to ignite the gas by putting a burning splinter into one of the bottles. By dropping a small piece of burning paper into the other bottle, see if the gas will support burning.

Observations.—(1) Does the carbon dioxide burn? (2) Will a splinter or a paper burn in it?

Conclusions.—(1) Does carbon dioxide burn? (2) Does this oxide support burning or combustion?

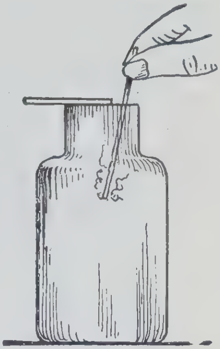


Fig. 309. What happens to the lighted splinter when it is thrust into a bottle of carbon dioxide? What is one important difference between carbon dioxide and oxygen?

Experiment III

Object.—To find whether carbon dioxide will extinguish (put out) a fire.

Apparatus.—A candle, a beaker, a bottle of carbon dioxide gas (Fig. 310).

Method.—Place a short piece of the candle in the bottom of the beaker. Light it. Then pour the bottle of carbon dioxide gas into the beaker in the same way that you would pour water into it.

Observation.—Does the candle soon go out?

Conclusions.—(1) Does carbon dioxide put out a fire? (2) Is carbon dioxide heavier or lighter than air?

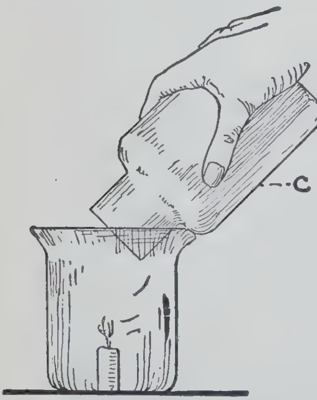


Fig. 310. C, Carbon dioxide. How do you know that carbon dioxide is heavier than air?

Carbon dioxide, a fire extinguisher.—Unlike air and oxygen, carbon dioxide does not support burning. Moreover, it is heavier than air and will therefore tend to sink to the bottom of a vessel that has air in it. When poured into the beaker containing the burning candle, it settled down on the flame, pushing away the air and thus putting out the

candle. Because carbon dioxide will not support burning, and because it is so heavy that it will settle on a fire and exclude the air, we make use of it in extinguishing fires.

Have you a fire extinguisher in your school? Have you ever seen one hanging up in a building as a safeguard against fire? The ordinary fire extinguisher consists of a metal tank to which is attached a short hose. In it is a solution of baking soda and a bottle of sulphuric acid. When standing in an upright position as shown in the diagram (Fig. 311), no carbon dioxide is produced within the extinguisher. When inverted, however, the acid runs out of the bottle, mixes with the baking soda, and rapidly forms carbon dioxide. (The acid acts upon the soda as hydrochloric acid acts upon marble.) Some of the carbon dioxide which forms rises in bubbles to the top of the liquid and exerts a downward pressure upon it. This pressure forces the mixture of acid and soda to escape rapidly through the rubber hose. As the mixture escapes through the hose, it continues to produce more and more carbon dioxide. When directed by the hose into a fire, both the carbon dioxide and the water of the solution aid in extinguishing the blaze. The carbon dioxide aids by settling on the fire and thus shutting off the supply of air from the burning material. The water aids in putting out the fire by cooling the burning material below the temperature at which it will unite with the oxygen of the air and by keeping the air from it.

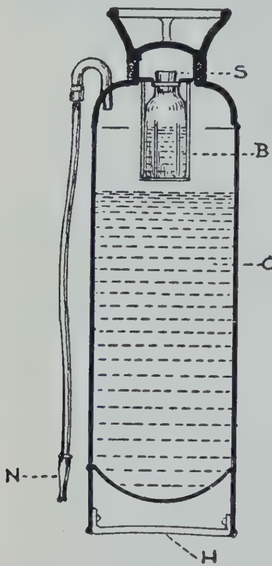


Fig. 311. Fire extinguisher. S, Loose stopper. B, Bottle of sulphuric acid. C, Sodium bicarbonate or baking soda dissolved in water. N, Nozzle of hose. H, Handle. To use the extinguisher, seize it by the handle, turn it upside down, and direct the escaping materials on the fire with the nozzle.

The effect of carbon dioxide on a person breathing it.—A long time ago, before safety lamps and electric lights were known, frequent explosions occurred in coal mines. During the explosion most of the oxygen of the air in that section of the mine was used up, and much of it was replaced by carbon dioxide, which formed in great quantities. Any person in the mine who escaped injury by the explosion quickly died unless he escaped from the mine at once. He could not live in air from which the oxygen had been used up. Let us consider the reason for this.

You will recall that a candle will burn in pure oxygen or in the oxygen of the air but not in carbon dioxide. This is because oxygen will unite with the materials of the candle to produce heat and light energy, while carbon dioxide will not. Similarly, foods that enter our bodies will combine with the oxygen of the air that we breathe to form heat and energy, but will not combine with carbon dioxide. We cannot therefore live in an atmosphere of pure carbon dioxide or in air in which the oxygen has been replaced by carbon dioxide.

Questions and Review

(1) What is the test for the presence of carbon dioxide? (2) Leave a little limewater exposed to ordinary air in a beaker for an hour or two in the classroom. Does anything form on the surface of the limewater? What must be in the air? Why must we keep the cork in a limewater bottle? (3) How could you show that wood and other plant and animal materials contain carbon? (4) What is formed when carbon burns? How do you know? (5) How could you show that there is considerable carbon dioxide in the air that we breathe out from our lungs? Compare the amount of carbon dioxide in ordinary air with that in exhaled air. (6) What materials are used to prepare carbon dioxide in quantities? How could you prepare it? If carbon dioxide were very soluble, could we collect it over water? (7) What is burning? Suggest why carbon dioxide will not support burning. (8) What is the action of carbon dioxide on a fire? (9) When a fire extinguisher is used, what two materials help to put out the fire? How does each act on it? Would you direct the escaping

liquid into the flame above the material that is burning or on to the burning material itself? Why? (10) (*a*) How would you prove that carbon dioxide is heavier than air? (*b*) If it is heavier than air, what keeps it from settling to any extent out of ordinary air? (*c*) Have you ever heard of a man suffocating in a well? Explain! If you lowered a lighted lantern into a well containing a considerable amount of carbon dioxide, what would happen? It is wise to test a well in this way before going down into it. (*d*) Would carbon dioxide have an opportunity to settle into a well in which the air is being continually stirred by winds?

PART IV

SPRING STUDIES OF PLANT LIFE

CHAPTER XLII

SPRING DEVELOPMENT OF TREES. CUTTINGS

I. SPRING MOVEMENT OF THE STORE OF SUGARY SAP IN THE STEM

Introduction.—Even before the snow is gone in the spring we see signs of the awakening of the trees. Have you seen sap dripping from a broken twig of Manitoba maple, or leaking out through a small cut or crack and moistening the bark? Sometimes on frosty spring mornings you find an icicle hanging where the sap was dripping the day before. Taste one of these icicles or a drop of the sap and see if the Manitoba maple contains any sugar. In Eastern Canada the sap is collected from the sugar maple and other maples by boring a hole in the side of the tree and inserting in it a spout, upon which a pail is hung.[1] In Chapter VI, we learned the use of this food stored in the maple stem.

A little sap may leak out of a tree or may run out of a hole made when the tree is tapped, but that is only a small part of the sap in the tree. Where is the great quantity of sap going that is moving up the stem, and what becomes of it? To answer these questions, recall how the tree prepared for winter. It shed its leaves (see page 33). Then think what

[1]An average tree gives about thirteen gallons of sap each season, and when this is boiled down it makes two-fifths of a gallon of syrup or three pounds of maple sugar. As this is less than one-tenth of all the sugar in the tree, the tree is only slightly injured by tapping.

it must do in the spring in order to obtain new leaves. It must grow them from food, and the food that it stored over winter for this purpose is in the rising sap. The first work of a tree in the spring is to raise the sugary sap up to the buds so that they may produce new leaves. We shall watch the growth of the buds on branches indoors and on the tree.

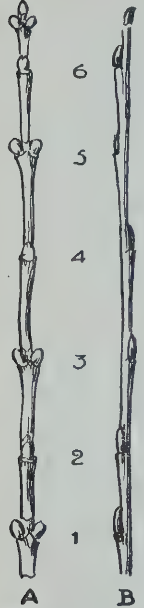


Fig. 312. A, Maple twig showing opposite arrangement of buds. How many vertical rows of buds are there along the stem? B, Willow twig showing alternate (spiral) arrangement of buds. Each bud is two-fifths of a turn around the stem from its neighbors.

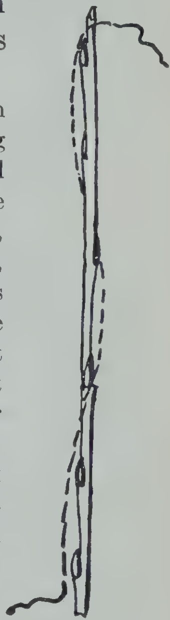


Fig. 313. Wind the thread around the twig from one bud to the next and find the spiral. Try this on long, straight twigs, where the spiral will be unbroken.

Preparation.—Before there is any growth of the buds on the trees out-of-doors, bring into the classroom, or into your home, small branches from a number of trees. These should be one-quarter to one-half inch thick, and should be carefully cut from poplar, willow, maple, cherry, and any other kinds that may be secured without injury to the trees. Be sure that you know from what kind of tree each one comes. If you do not know the names of the trees, ask someone, or refer to *Native Trees of Canada* (see page xxxiii). Use the pictures and descriptions in that book to identify the trees of your district that you do not know. In cutting a branch from a tree, make a slanting cut with a sharp knife across the branch. If the whole branch is being taken, cut *close* to the main stem on which it grew. Do not leave a short stump to die and decay. Place the branches in vessels of water in a warm room as soon as possible after they are brought in. It is best to cut an inch off the lower end of each branch *after it is under the surface of the water.* This removes air bubbles from the sap tubes. Branches will do better in crocks or pails that do not admit much light. If stuck through holes in heavy cardboard covers, they will last longer and require less attention than if the crocks are left open. Keep the branches well supplied with water, and if they become slimy, wash them, cut pieces one inch long from the ends, and give them fresh water. After the leaves are well out, a plant-food tablet may be added to the water.

Having placed these branches where they will be fairly warm and will have plenty of moisture, we shall leave them until they show signs of growth. Be sure that you have the specimens clearly labelled with the names of the trees. We shall study these branches again in Section III (page 382). While they are growing, we shall examine the arrangement of buds on other twigs.

Fig. 314.* Flowers (below) and fruits (above) of elm. These fruits fall in early summer and often grow very quickly to little trees.

II. ARRANGEMENT OF BUDS ON TWIGS

Preparation.—Two twigs will be required for each member of the class. One of these should be from maple, ash, lilac, honeysuckle, or other woody plant having its buds arranged as in A, Figure 312. The other should be willow, poplar, birch, oak, or other woody plant having its buds arranged as in B of the same figure. Each of these twigs should be long enough to show at least six nodes or joints. The nodes are the places on the stem from which buds grow out. Each pupil should also be provided with a piece of thread somewhat longer than the twig marked B.

Let us now examine the two kinds of bud arrangement to be found on our specimens.

Opposite arrangement of buds and leaves.—How many buds grow at each node along the stem in the twig that resembles A? Look carefully at the buds growing at any six nodes in order along the stem.

*The illustrations of the flowers of the elm, oak, birch, ash, white spruce, willow, poplar, and box elder in this chapter are reproduced from *Our Trees and How to Know Them* by Arthur I. Emerson and Clarence M. Weed, by courtesy of J. B. Lippincott Company, Philadelphia.

Were the leaves that grew on this twig last summer arranged in pairs as these buds are? Look for the leaf scar just below each bud. Such an arrangement of buds or of leaves is called *opposite* or "opposite in pairs." At the top of the twig there is usually one odd bud. It is called the end bud, or *terminal bud.* The others are side buds, or *lateral buds.* Notice that each pair of lateral buds is a quarter turn around the stem from the pair above and below it.

Fig. 315. Flowers and fruit of oak. What do you call these fruits? Why is this oak called "bur oak" or "mossy-cup oak"?

Note-book Record.—Lay out a page for two drawings of twigs with buds. The page title may be "Arrangement of Buds on Twigs." In the left space, show the twig with opposite buds that you have just examined and give it the title, "Twig of . . . Showing Opposite Arrangement of Buds."

Alternate arrangement of buds and leaves.—Now look at the twig of willow, poplar, or other tree with buds arranged as in B. Are the buds opposite one another? How many buds are there at each node? Is the bud at the node marked (2) straight above the bud at the node marked (1)? Is the bud at (3) above the bud at (2) or (1)? Can you find any definite arrangement in these buds? Any arrangement of buds that is not opposite may be called *alternate.* At first glance these buds do not seem to have any definite arrangement; they seem to be scattered at random along the stem and all around it.

Scientists often meet a problem like the one you now have met,—to find a system of arrangement where there does not seem to be one. What do they do? They try all the arrangements that they already know, as we have tried the opposite arrangement, and if none of these fits the new specimen, they try to think of new arrangements and test them to see whether they fit the specimen that they are observing. They keep trying until they find one that fits.

Fig. 316. Catkin of flowers of birch. Which of the others does it resemble?

Look at your twig again carefully and try to discover what kind of alternate arrangement it shows. It may help if you use a thread. Lay the thread along the twig from the lowest bud to the next, and then on to the next, taking the shortest way round in each case to reach the next bud (Fig. 313). Do the buds seem to be in a spiral arrangement on your specimen? Alternate buds are usually in spirals.

Fig. 317. Flowers of ash. These do not hang down, being quite short. The clusters on the left become "key fruits" something like those of the maple. Look for both in your collection of seeds and fruits.

The willow, the poplar, and similar twigs have their buds arranged in spirals. How must their leaves have been arranged the previous summer? In this arrangement, does one leaf shade the next leaf below it? Are the

leaves spaced around the stem so that they all receive a share of the sunlight?

Fig. 318. Flowers of white spruce. These are catkins like the stamen catkins of the willow. The seeds are produced in cones.

Note-book Record.—On your diagram page draw a twig showing the spiral arrangement of buds.

III. OPENING OF THE BUDS OF TREES

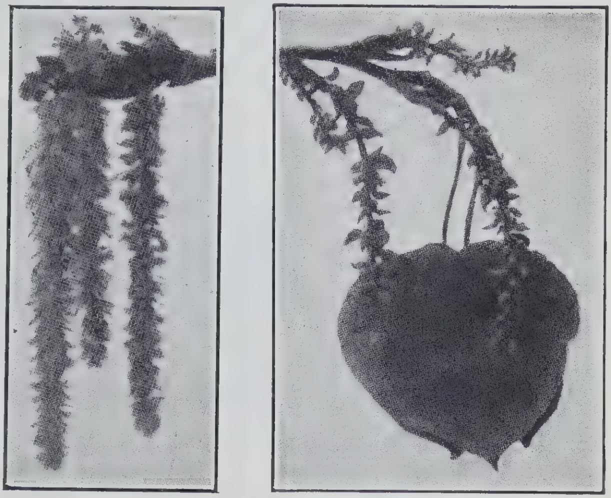
We may now return to the branches that we placed in water. When the buds begin to open, observe carefully what becomes of the protecting bud scales. Do they grow into leaves, or do they fall off? What comes out of the bud first,—stem, leaves, or flowers?

You will see, as the buds open more widely, that some are sending out little twigs with leaves on them, and others are sending out little twigs with flowers on them. From their flower buds the willows and the poplars send out long narrow tassels or "catkins" of flowers. Those of the willow are yellow or green and stand upright (Fig. 319). Those of the poplar are gray or reddish and hang down (Fig. 320).

Fig. 319. Flowers of willow. Those on the left are catkins of yellow stamen flowers. Those on the right are green catkins of pistil flowers changing to seed pods.

Look for the reddish brown tassels of stamens of the maple flowers (Fig. 321). Notice the other flowers shown in the diagrams, and look for tassels on your specimens or out-of-doors (Figs. 314, 315, 316, 317, and 318).

Flowers of maple, willow, and poplar.—You have found that some maple trees produce seeds while others do not (see *Suggestions*, page xvii). Perhaps you can understand the reason for this now that you have before you the flowers of the tree. Look carefully at Figure 321 and find on your specimens that are in water or on trees out-of-doors, the two kinds of flowers. The brownish tassels shown on the right are stamens. These flowers that grow stamens have no pistils. Can they produce any seeds? They have a tiny calyx, and the inner bud scales grow large, but they have no corolla. You will find that on any one maple tree the flowers are all alike. Do you understand now why some maple trees never produce any seeds?



A B

Fig. 320. The two kinds of flowers of poplar. A, Stamen catkins. B, Pistil catkins. Each pistil has formed a pod with fluffy seeds in it.

The maples that do produce seeds have flowers like those shown on the left of Figure 321. These flowers have pistils, but have no stamens. Can they produce any seeds without help from other flowers? What do they

need? When they receive pollen from the stamen flowers, they grow into the winged fruits that we sometimes call "bunches of keys," or "maple seeds" (Fig. 21). The trees that have pistil flowers have no stamen flowers and are therefore dependent upon the wind or upon insects to bring them pollen from other trees that have stamen flowers.

Examine the willows and notice whether their catkins have stamen flowers and pistil flowers on the same tree or on separate trees (Fig. 319). The yellow catkins of the willow are clusters of stamen flowers, and the green catkins are clusters of green pods formed from the pistils. Do you find any insects visiting willow flowers? Though these flowers have no calyx or corolla to attract insects, they have nectar. Are there many other kinds of flowers in bloom to attract the insects while the willows are in bloom? Do they need very bright colors?

Fig. 321. The two kinds of flowers on box elder or Manitoba maple. Those on the left become the "bunches of keys" or fruits that we see still clinging to the tree even in winter.

Look again at the two kinds of catkins of the poplar (Fig. 320). They are not even as bright in color as those of the willow, and they have no nectar. Do you think that they depend upon insects to carry their pollen? Shake a poplar branch that has its catkins in bloom like those in Figure 320, A. Can you see the cloud of pollen grains that falls from it? Plants that depend upon the wind to carry their pollen must produce a great deal of pollen because much of it is wasted. When it blows away, nearly all of it must be wasted if there are not many pistil flowers close by.

Practical Exercise

On a page of your note-book keep a calendar of the dates upon which five kinds of trees show (*a*) first signs of buds opening, (*b*) flowers fully open, (*c*) leaves fully grown, (*d*) seeds ripe and falling.

Collect short but healthy twigs showing buds and flowers of common trees and mount them in a formalin solution, sealed in test-tubes. These mounts will be like Figure 348. Cut flat corks from long ones with a razor blade.

Can you suggest what advantage is gained by trees that open their flowers before their leaves come out? Flowers, you will remember, must have pollen to enable them to produce seed. Some tree flowers depend upon insects to carry their pollen, and others have their pollen carried by the wind. Are the flowers that depend upon insects to carry their pollen more readily seen when there are no leaves (e.g. willow)? Are those that depend upon the wind to carry their pollen more exposed to the wind when there are no leaves (e.g. poplars)? Doubtless, if the wind-pollinated trees had leaves, the leaves would receive much more of the pollen than would the flowers. We readily see, therefore, the advantage which trees gain by opening their flower buds before their leaf buds.

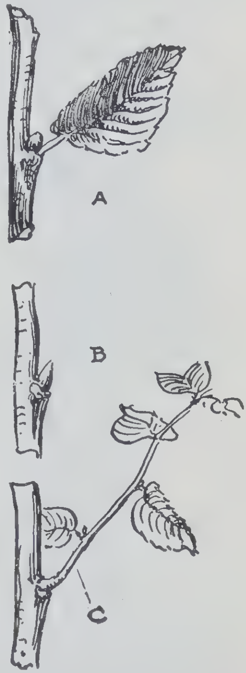


Fig. 322. Diagram showing what grows from a node on a twig: A, in the summer, B, in the winter, C, the next summer. Do leaves grow in the same places on the tree this year and next?

When the leaves are well out of the buds, observe one other point carefully, namely, that from each bud there is growing, not a single leaf, but a *twig with several leaves upon it.* Figure 322 shows what grows in successive seasons from one node of a twig. In the first summer it produces a leaf with a bud in its axil or angle (*A*). In

the autumn the leaf falls, and the bud remains on the twig over winter (*B*). In the spring and summer this bud grows to form a new twig with leaves or flowers on it (*C*). A node, therefore, grows a leaf only once, and the new leaves that grow on a tree in the spring are not in the places of the leaves that fell off last fall, but are all on new twigs.

IV. GROWTH OF ROOTS ON BRANCHES AND STEMS

When you have had your branches of various trees and shrubs in water for some weeks, you will probably find that some of them have sent out roots along their sides. The willow is likely to be the first to do this. If the branch with these roots were planted in soil, might it grow up to be a new willow tree?

Fig. 323. Cutting of tradescantia (wandering Jew) sending out roots in water. This cutting is ready to plant in soil.

Have you seen the willows along the river broken down by the ice in the spring and partly buried in the mud? Are the willows killed by this rough treatment? Why? Is it an advantage to trees or other plants to be able to send out roots from their stems?

Cuttings.—We have seen that new plants may be started from branches placed in water or in moist soil. We frequently use this method to secure a number of plants from one plant instead of waiting for it to produce seeds. Branches or parts of the stem cut off for this purpose are called "slips" or *cuttings* (Fig. 323).

Practical Exercise

Start some cuttings of the common tradescantia (wandering Jew) or other plant in test-tubes of water, keeping the tubes filled with water

and the outside covered with brown paper, as the tumblers were covered in the germination experiments. Trim off the leaves from the nodes that are under the water. The plants will then continue to grow for several weeks. Tradescantia cuttings send out roots covered with root hairs. Pass them about the class so that they may be clearly seen by all.

Each member of the class should start a cutting from a house plant at home or in the classroom. Cuttings may be started in sandy soil or in water, though some may not start well in water. Those started in water should be planted in soil soon after roots appear. Figure 324 shows how to prepare a cutting for planting. If no others are available, spare cuttings of wandering Jew may be used. The cuttings should be looked after until they are well started; then they should all be brought to the classroom and labelled plainly so that each member of the class may become acquainted with every plant. These plants will form suitable ornaments for the classroom windows. Perhaps you may wish later to exchange your plant for one of another kind that you have not at home.

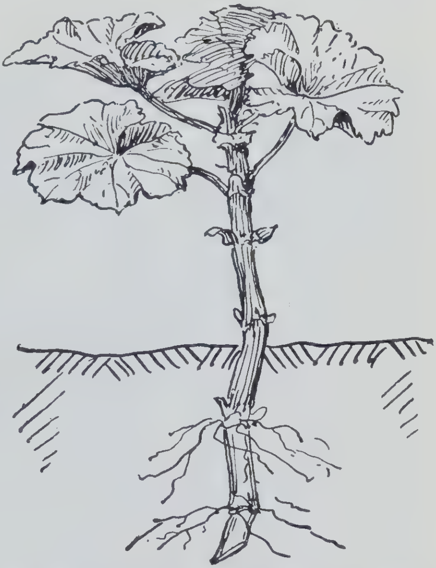


Fig. 324. To prepare a cutting for planting, cut in a sloping direction with a *sharp* blade just below a node. Cut the leaves from two or more nodes and bury this part of the stem in the soil (or water).

Question Outline

(1) Where is food stored over winter in a tree? (2) What use is made of this food? (3) Explain how the buds (or leaves) are arranged on a twig of maple or other plant with "opposite" arrangement. (4) What advantage does the plant gain by having the buds at each node part way round the stem from those above and below? (5) What comes out of the buds of willow, poplar, and maple in the spring? (6) What advantage do trees gain by having their flowers come out before their leaves? (7) What grows from each bud that opens in the spring? (8) Do leaves grow in the same places year after year? (9) When willows are broken down by the ice and partly buried in the mud, what becomes of them? (10) How do you cut and trim a branch when making a "cutting"?

CHAPTER XLIII

OUR SHADE TREES AND FORESTS

How living trees are useful to us.—In observing how plants prepare for winter (Chapter VI), we noticed the two different shapes of trees and pointed out that those of

Fig. 325. This house has good shade trees. Was it worth while to plant them and care for them after they were planted?

one shape give good shade, while those of the other shape make good poles and lumber (Figs. 37 and 352). When we use trees for shade, we use the living tree, and for this purpose it can be used over and over again by various people. It continually grows larger and becomes more useful as a shade tree and yet is not destroyed or used up.

Shade trees.—Why do people plant shade trees around their homes and grounds (Fig. 325)? Probably chiefly because everyone likes trees. We like trees, not only because they are ornamental, but also because they provide shade and shelter. On hot summer days they offer us cool inviting spots in which to rest. They furnish protection from the sun because their leaves stop the rays and use their heat to evaporate moisture. Thus the sun does not heat the leaves, or the ground beneath the trees. In the summer, shade trees thus protect our lawns and gardens from the heat of the sun and help to keep the air cooler about our houses. In the winter, they protect the houses and the less hardy plants against the cold, dry winds.

Courtesy Burton Gresham.

Fig. 326. A street with shade trees. Do the trees make this a more desirable street to live on than it otherwise would be?

On the streets of cities and towns and along country roads shade trees are especially valuable (Fig. 326). They keep the pavements and roadways from becoming greatly heated by the sun. Have you ever walked along a road or street that, through lack of trees, was very hot? Cities that have many trees along their streets and in their parks are much more comfortable and more healthful to live in than cities that have only a few trees or none at all. Every tree that grows on a street or in a garden helps to cool the air of the city. In cities, however, trees should not be planted very close together; they should be arranged and trimmed so that a breeze may blow through them. Do you think that the

trees along the streets of a city help to protect the houses against the cold winds of winter and to prevent the snow from drifting? Are they useful in wind storms? Shade trees about our homes or on the streets of towns and cities are very valuable for shade and for shelter.

Shelter-belt trees on farms.—Most of the farm houses on the prairie are surrounded by shade trees which give protection in summer and winter. Many of the farms have also "shelter belts" of trees that prevent the winds of

Courtesy Forest Service, Ottawa.

Fig. 327. This farm has a good shelter belt of trees. Of what value is it?

winter from sweeping through the farmyard unchecked and drifting the snow deeply about the buildings. The snow is held in the shelter belt where the water from it can be of use to the trees in the spring and summer. Look at the farmyard shown in Figure 327 and decide whether it was worth while for this farmer and his family to work hard twenty years ago to plant the trees for a shelter belt. Are their buildings and barnyard well protected now? Contrast with this the farmyard shown in Figure 328.

Tree planting.—Trees grow slowly. We should not forget that the trees that are now large enough for us to

enjoy we did not plant. They were planted by someone else, and we are reaping the benefit. There is no better way in which we can show our appreciation of the trees that have been planted for us than by planting more trees (Fig. 329). If you plant a tree during your school days, by the time you are grown up, it will reach a fair size, or even a large size if it is a rapid growing kind like cottonwood, poplar, or

Fig. 328. This farmyard has very little shelter. Will it be improved when the shelter belt has grown up? Is it important to place the shelter belt properly?

maple. In its life-time it will doubtless give shade and protection to many people. It would be an interesting experiment for you to plant one tree every spring or fall and to keep a record of them all in your diary. In later years you might visit the places that you had thus helped to beautify and see the results of your work. In many places to commemorate people or events it has become the custom to plant trees instead of erecting monuments of stone or metal.

How to protect trees against injury.—Trees have a layer of soft growing material just inside the bark. Each year this layer forms a new layer of wood and of bark, thickening the tree. Have you found this moist, slippery layer in a willow stem when making a whistle?

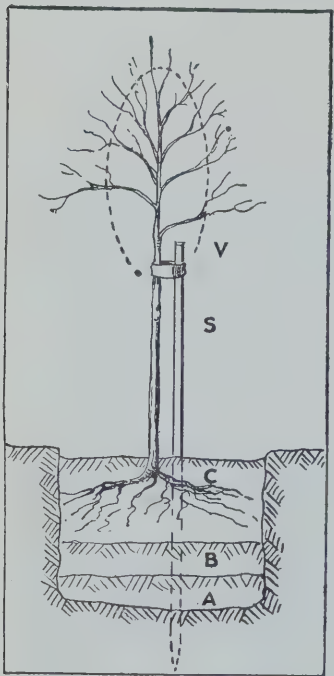


Fig. 329. How to transplant a tree. Prune back the branches to a narrow oval (V). Dig a generous-sized hole. Cultivate the bottom (A). Put in a layer of garden soil (B). Then bury the roots in garden soil about two inches deeper than they were in their former positions, tramping the soil about them very firmly (C). Nearly fill the hole, leaving a hollow. Keep the soil moist. Support the tree with a stake (S) driven into solid ground below the hole.

In the soft bark just outside this **growth layer** are the **sap tubes** that carry the sugary food made by the leaves down the stem to the roots of the tree. Knowing this, it is not difficult to understand that trees are easily injured. If a ring of bark is cut from a tree or is eaten away by rabbits or field mice (Figs. 330 and 331), the sap runs out, and the tree dies. Rodents often do much harm to young orchards in this way. If the inner bark is bruised, the sap tubes are damaged, and, if the bark is cut or broken, disease germs are able to enter and cause decay. A small wound in the inner bark of a tree often admits disease germs that later make the tree hollow and finally kill it.[1] A tree that has taken many hundreds of years to grow may be killed in a few minutes by someone who does not understand how easily trees are injured.

[1]Cutting initials into the inner bark of a tree is very injurious. It gives entrance to disease germs that cause first a "sore" and then an ugly scar upon the tree. Under the scar the disease germs work and spread until the tree is killed. People who understand trees do not cut initials in their bark.

People who are anxious to protect their trees often do them serious injury because they do not know about the sap tubes in the bark. A wire or rope bound around a tree (Fig. 332) becomes constantly tighter as the tree grows thicker and soon crushes the delicate sap tubes in the inner bark. This stops the flow of sap and causes more wood to be formed near the injury. The result is an ugly swelling and serious injury to the tree. A wire or rope carrying a heavy load, such as a hammock or clothes-line, tied around a tree even for a very short time, will injure the inner bark and check the growth of the tree probably for years (Fig. 333, A). To protect the shade trees about our homes and the trees in our parks and forests, therefore, we should be careful to avoid injuring the inner bark in which the sugary sap is flowing downward to feed the roots and the lower part of the stem. The outer bark also is important. It is the natural protection of the tree against injury and disease.

Fig. 330. Tree "girdled" by rodents. Why will this tree die?

Fig. 331. Tree protected by wire netting to prevent girdling by rodents.

A tree should not for its own good have anything attached to it, but if it is necessary to make it carry a load, or to fasten large limbs together to prevent them from breaking in the wind, it can best be done by means of screw-eyes or eye-bolts as shown in Figure 333, B. If a clean-cut hole not more than one-twelfth the diameter of the stem is bored and partly filled with pine-tar (or even paint) and a clean, tight-fitting bolt is immediately screwed in, there will be little chance of

Fig. 332. Tree injured by tight binding. The tree thickens and tightens the wire so that it crushes the sap tubes carrying food downward in the bark.

disease germs entering the inner wood. The bark close around the openings should be trimmed back with a sharp chisel so that the washers may rest against a flat surface of *wood.* The exposed edges should be kept well protected by pine tar or paint. A scar will form over the nut of the bolt, but the eye of the bolt, since with its load it cannot be covered by new wood, must be kept painted.

This method of attaching a load to a tree destroys a few of the sap tubes, but leaves the majority of them uninjured. A wood-screw may be used if the load is not very heavy

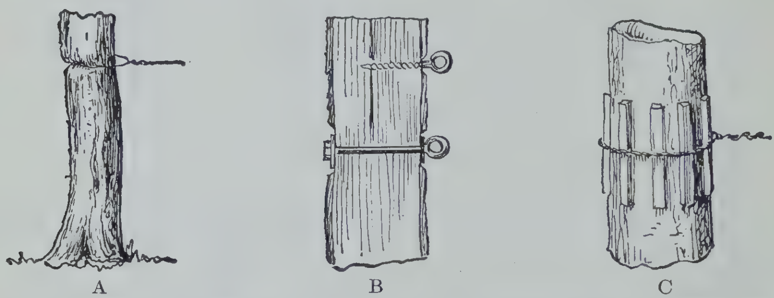


Fig. 333. Methods of fastening a load to a tree. *A* shows the result of using a wire. This will kill the tree. *B* shows two good methods, and *C* shows a safe way to attach a moderate load for a short time.

or if the tree is not very thick. It makes only one opening. The method shown in Figure 333, C, lessens the damage done by tight binding and is suitable for attaching a load for a short time. If left in place long, the sticks will injure half of the sap tubes in the stem. Small trees that require support when transplanted should be held firmly, but not tightly, by a ring of rubber hose, a piece of tire, or other soft material that will not chafe the bark (Fig. 329).

Trees require protection against germs also when they are being pruned. If a branch is to be removed, it should be cut *close to the main stem* so that a short stump will not be left to die and provide a breeding place for bacteria, which would make their way into the trunk and decay the heart

wood of the tree. Sharp tools should be used, and the wound should be kept painted until it is covered by the scar (Figs. 334 and 335). Any accidental wound should be similarly sealed up with paint or pine tar to prevent infection, which causes decay and shortens the life of the tree.

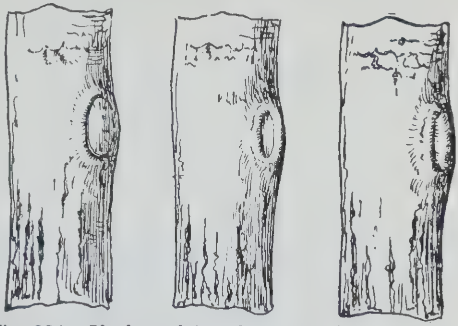


Fig. 334. If a branch is to be removed, it should be cut close to the main stem. New wood and bark then grows inward and completely covers the wound.

The living forest.—Like the trees that we plant about our homes, the forest trees give us welcome shade and shelter from the wind. But they do much more than this. The forest is a wonderful place in which we may find stories quite as interesting and wonderful as the fairy stories that we read but never expect to come true. It is a delightful place in which to spend a holiday, whether it be a month's camping or only an overnight hike. Each summer many thousands of people from cities and farms make their way to the lakes in the forests for a change and a rest. To a dweller on the prairie the forest is like a new world of plants and animals, of rocks and streams, quite different from those of the plains. To one who has always lived in the forest country no other place is home.

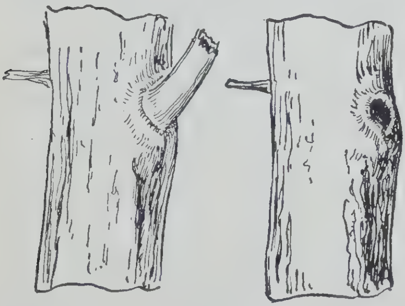


Fig. 335. If a short stump of the branch is left, it dies and decays. The bacteria of decay get into the trunk before the wound can be healed over.

In the prairie region, and just north of it, are many thousands of lakes with wooded shores that make ideal holiday homes for all who enjoy camping in the woods. In

a woodland camp we may live out-of-doors, cook over a camp fire, swim, fish, and practise woodcraft in other ways. There, also, we may visit the animals in the homes that they make for themselves in the trees, in the ground, or in the water. We may see the rocks, the springs, the streams, the trees that we have read about, and, with a little help from someone more skilled than ourselves, we can read many interesting stories in this woodland home.[1] In return for all the pleasures that the woods afford, we should use every means in our power to protect the trees against their worst enemy—fire.

The forests not only provide us directly with pleasures, but indirectly they also provide us with necessities such as clothing and food. The forests provide homes for most of our fur-bearing animals, from which we obtain warm, comfortable clothing to protect us in our severe winter climate. The lakes in the forest are the homes of important fishes that add to our supply of wholesome and economical foods.

The forests also help to keep us healthy and comfortable while we are living in our own homes. The innumerable leaves of the trees, while making their food, purify the air for us to breathe (see Chapter XLVI) and also evaporate into the air great quantities of water vapor. This evaporation cools the winds blowing over the forests. Most of the moisture falls again as rain many miles from the forest where it evaporated.

In a dry summer season, without the forests many of our streams would be in danger of drying up. The roots of the forest trees and the mass of dead leaves and twigs on the forest floor hold great quantities of water as the snow melts in the spring. Then, when the hot, dry summer comes, this

[1]There are many books from which you may learn how to live in the woods comfortably on week-end hikes or for longer periods, and others from which you may learn what to do and what to see in the woods. Consult one of the following: *Boy Scouts' Handbook* (Boy Scout Headquarters); *Book of Woodcraft* by Ernest Thompson Seton (Doubleday, Page); *Book of Camping and Woodcraft* by Kephart (Outing Co.).

stored-up water is slowly soaking down through the ground and feeding the springs, so that the streams and rivers from well-wooded regions never run dry. Where the forests are protected, they prevent spring floods and keep the streams flowing throughout the summer. Is this helpful to farmers and especially to ranchers living along the river valleys? Is it helpful also to regions that need water for irrigation, and to cities that require water for drinking and water-falls to

Courtesy Forest Service, Ottawa.

Fig. 336. This forest has been burned. The leaves and moss have burned off the ground, leaving the soil exposed. Will the spring rush of snow water wash away this soil? Will the rivers flood? Will the springs on this hillside flow all summer?

provide their electric power? When the forests are allowed to burn, what happens (Figs. 336 and 337)?

The forest is a great living part of our country that belongs to all the people. It helps us to keep healthy and comfortable, no matter where we live; it houses our wild animals; it regulates our streams and rivers; and it provides us with a great camping ground where we may rest or watch the living things, or where we may explore in search of treasures or play to our hearts' content. There is plenty of room in the woods for all. To earn the right to go there,

we have only to remember that, since the forest belongs to all, we must do our utmost to guard it against fire.

Trees taken from the forest.—In the living forest there are so many trees that some of them may be removed without harming the forest. In fact, if some of them are not removed, the oldest trees die off and decay, finally crashing down upon the younger trees. The forest therefore benefits

Courtesy Forest Service, Ottawa.
Fig. 337. The soil has all been washed away after a fire, leaving the bare rocks. Can a new forest grow up here?

by the removal of some of its largest trees, and we have found many uses for the wood of their stems.

Uses of forest trees.—Trees that are cut from the forest are sawn into logs, many of which are used with little further change. Poles for carrying telephone wires, piles used in foundations, and pit props used in mines are tree stems or logs just as they are cut from the forest. With a little more work the logs become railway ties, and with more work still they are made into lumber. The lumber is built into bridges, houses, and many other kinds of building. Lumber is also used in hundreds of other ways. What are some of them?

Practical Exercise.—Refer to the list that you made in Chapter I and make a more complete list of the *uses* of trees to people. Write down the things made, rather than the names of trees.

Value of the crop of forest trees.—A good-sized log as it is cut from the forest is worth about $5.00. When it is sawn into lumber, the work that is put upon it makes it worth about $13.60. When made into window sashes and doors, the lumber would be worth about $23.15. Do you think that it would be worth more or less than this in the form of chairs or pencils? A log worth $5.00, when ground into pulp and made into paper, is worth about $17.60. The value of the crop of wood that we get from our forests is very great, being second only to the value of our wheat crop in an average year.

How our forests are damaged.—We have mentioned some of the ways in which our forests are damaged by enemies. *Insects* eat the leaves and bore into the wood of the stems of trees (Fig. 55).

Disease germs floating about in the air may enter a tree through any small cut or other wound in the bark and injure the tree, just as disease germs may injure us. Careless lumbermen damage young trees when they are cutting down and taking out the old ones. Each of these enemies does great damage, but the worst enemy, *fire*, causes greater loss than all three of these together.

Often during a hot, dry summer whole settlements in the forests are destroyed, and many lives are lost (Fig. 338). The people who live in forest settlements and in forest towns have always the danger of fire in their minds. They must always fear, as long as there are people in the forests who are careless with fire, that some day they will have to flee from their homes and take shelter in the nearest lake to save their lives. Try to imagine how you would feel if you were forced to see your own home burned to the

ground and members of your own and neighboring families perishing in the flames. Then you will realize how worth while it is to be *sure* that you have put out the *last* spark of your camp fire before leaving it. In a recent period of five years there were 26,000 forest fires in Canada, which cost the people of this country $70,000,000, and cost a number of people their lives. Of these fires 13,000 were

Courtesy Forest Service, Ottawa.

Fig. 338. A forest fire driven by a wind. Is it worth while to be sure that your camp fire is out before you leave it?

known to have been caused by careless campers, tourists, and settlers, and by carelessness along the railways.

How much forest have we in Canada?—We have only to travel across our country to see that we have a vast extent of forest land. More than half the area of Canada, in fact, is rough land and better suited for growing forest than for growing grain. But not all of our forest land is now covered with good forests. About 60 per cent of our original forests have been burned, and we have cut down and used about 13 per cent of them. There remains to us, therefore, only 27 per cent of the original forests that were

here when our forefathers first came to this country (Fig. 339). New trees are growing in our forests about as rapidly as we are using the old ones for lumber, but not rapidly enough to make up for the trees that are burned and destroyed by insects and disease.

We sometimes hear people say, or read in books or in papers, that Canada has "unlimited wealth" in her forests, fields, lakes, and mines. This is not true. We have great forests in Canada, but they are not so large that we can afford to waste them. They are now only a little more than one-quarter as large as they were at one time, and, if we do not protect them against fire, they will soon be exhausted. Experts who have studied our forests for many years tell us that, if we continue to use our forests and to waste them at our present rate, most of the available timber will be used up in twenty-five years. Therefore, it rests with those Canadians who are now in school to decide whether or not Canada is to have any valuable forests from which to make lumber in the future. Could we do without forests? Must we do something to prevent our forests from disappearing?

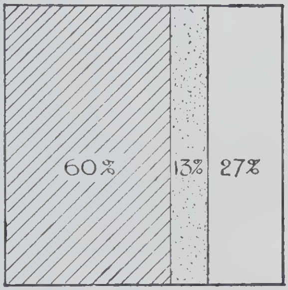


Fig. 339. Diagram showing the parts of our original forests that we have burned and used. We have only 27 per cent of them left.

How can we make our forests last "forever"?—What may we do to enable our forests to last longer than twenty-five years? We have learned how birds protect trees against insects. To help them in this work we have only to protect and encourage birds (see Chapter XII). Our chief means of protecting trees against disease lies in helping them to protect themselves. If the bark is not damaged, it will keep out most disease germs. Lumbermen, in taking out large trees, should be careful to avoid injuring the bark of smaller

Courtesy Forest Service, Ottawa.

Fig. 340. Our northern forest and lake country showing aeroplane forest patrol and a forest fire. What valuable products come out of this part of Canada?

trees so that they, in their turn, may grow to full size. Care should be taken also to avoid bringing in from other countries plants that are carrying diseases. Such diseases spread rapidly among our trees and do them more harm than the diseases to which they are accustomed.

To protect our trees against fire we must also do what we can to assist our forest rangers and forest airmen, who are on duty throughout the season, to check fires that are started. These men are saving our forests and protecting the lives and property of the people who live in the forest country. The best help that we can give them, of course, is to *guard against starting forest fires.* The work of carrying one or two pails of water to put on the ashes of your campfire is a small price to pay for the satisfaction of knowing that *your* fire will never spread and kindle the forest (Fig. 340).

If we could prevent all damage by insects and disease and all loss by forest fires and other damage, our forests would grow almost rapidly enough to supply us with all the lumber that we require. But we cannot stop all these losses immediately, and moreover each year we shall need more lumber, as the number of people increases. How, then, shall we prevent our forests from disappearing? *We must plant new forests* to replace those that are being used up and wasted.

If we plant new forests, we shall be growing crops of trees as we now grow crops of wheat (Figs. 341, 342, and 343). But a forest crop can be harvested only after it has grown for thirty or forty years. Therefore, to keep our forests as large as they are at present, we have only to plant enough trees each year to replace those that are used up and wasted. If we need larger forests, we must plant more trees than we are using, and wait for them to grow (Fig. 344).

Courtesy Forest Service, Ottawa.

Fig. 341. Planting a new forest. Notice the size of the seedling trees in the pails and along the furrows. (See Figures 342 and 343.)

Courtesy Forest Service, Ottawa.

Fig. 342. The pine trees at the age of ten years.

Courtesy Forest Service, Ottawa.

Fig. 343. The same pines at the age of twenty years. They are now about twenty-five feet high.

The men of the Forest Service of the Dominion government are doing excellent work both in protecting the forests against their enemies and in planting new forests. Look

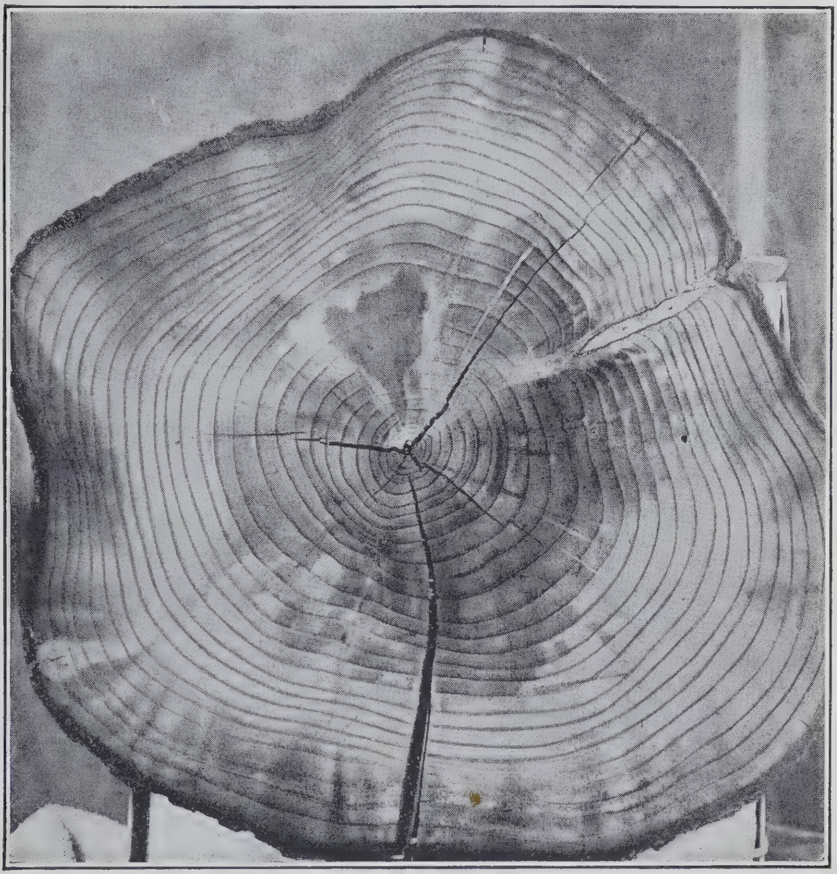


Fig. 344. End of a white spruce log showing layers of wood added each year. How many years did it take this tree to grow?

at Figure 340 and consider that we have thousands of square miles of forest lands on level country like this and in the mountains. Protecting the forests is a great work and requires many men.[1] Of what use are aeroplanes in this work?

[1]Read the bulletins on forest protection issued by the Forest Service, Ottawa.

In addition to protecting the forests, the Dominion government and some of the lumber and paper companies are planting new trees on the land from which trees have been cut or burned (Fig. 341).

Our forests need not disappear. They will last as long as we protect them against their enemies and continue to plant new trees where we are using the forest more rapidly than the young trees are growing up. The management of forests in such a way as to prevent damage, avoid waste, and increase the crops of useful forest products is called *Forest Conservation.*

Question Outline

(1) Why do you prefer a house that has trees planted around it to one that is bare of trees? (2) A good shelter belt increases the value of a farm by at least a thousand dollars. How? (3) What harm may rodents do to trees? (4) Why is a tree killed by having a ring of bark eaten off its stem? (5) Why does a small wound sometimes cause serious injury to a tree? (6) What harm is done by a tight band around a tree? (7) How does a band placed loosely around a tree become tighter year by year? (8) Why does it injure a tree less if we attach a clothes-line to it by means of a bolt through the stem than by tying the wire around the stem? (9) How may germs be kept out of the stem where the bark has been cut? (10) How should a transplanted tree be supported to prevent the wind from loosening it? (11) Do you enjoy camping in the woods? Why? (12) What is your first duty when you enter a forest? (13) How may you be sure that your camp-fire will not endanger the forest? (14) What enemies has the forest besides fire? (15) How may we make sure that our forests will supply us and our descendants with wood for lumber and other uses as long as it may be required?

CHAPTER XLIV

ROOTS AND THEIR USES

The first root of a plant.—When a seed commences to grow in the spring, it sends out a sprout (Fig. 345). Have you seen whether the sprout grows upward or downward? Among the specimens in your school collection there are probably some sprouted seeds preserved in formalin. If not, sprout some seeds and preserve them[1] so that there will be some in your collection when next required (Fig. 346).

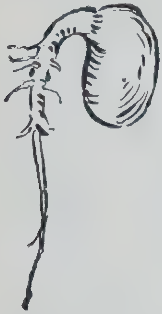


Fig. 345. The first sprout is always a root. Why does the young plant need a root before it has leaves?

If we examine sprouted seeds, we find that the first sprout always forms a *root*. What does the young plant in the seed need most when it begins to grow? It has enough food stored with it in the seed to last until it can grow some leaves, but it can soak up only a very little water through its skin. What is, therefore, the first work of the root?

Fig. 346. Sprouted seed preserved in 3 per cent formalin in a shell vial.

Common forms of roots.—The first or *primary* root of a seed grows downward for a short distance and then develops small branches from its sides. Many plants have roots of this form, even when they are full-grown,—Frenchweed and peppergrass, for example. A root of this form, having one primary or main root much larger than any of its side branches, is called a **tap root** (Fig. 347). Many tap-rooted plants use their roots for storing food. As the quantity of food in the roots increases, the

[1]For preserving specimens use 3 per cent formalin solution (see Appendix, Sec. 23). For method of sprouting seeds see *Germination* (page 211).

roots become thicker and fleshy, like a carrot or radish or turnip. These are *fleshy tap roots* (Fig. 349). Bring into the classroom a thin tap root and a fleshy tap root and preserve them for the collection (Fig. 348).

Fig. 347. Thin tap root as in pepper-grass.

Many other plants, after they have well passed the sprouting stage, develop roots consisting of a great number of fine branching threads, or fibres, of about equal size. Roots of the grasses and common plantain are of this kind. They are called **fibrous roots** (Figs. 351 and 352). Which form of root, tap or fibrous, has the more secure hold upon the ground? Test this by pulling up plants of about equal size in the same kind of ground—some with tap and some with fibrous roots. Find a fibrous grass root of medium size and preserve it in a quart sealer.

A few plants, such as the dahlia, the peony, and the sweet potato (not the ordinary potato), with roots that are somewhat fibrous, store food in the fibres (Fig. 350). The fibres then become thick, as do the fleshy tap roots, and form **tuberous roots** (*tuber*, a swelling).

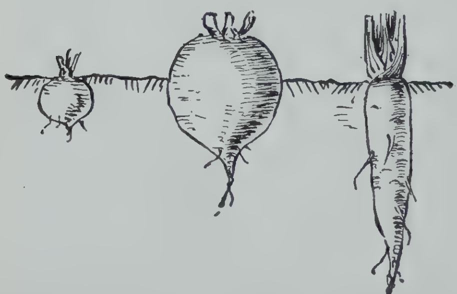


Fig. 349. Three common fleshy tap roots—radish, turnip, carrot. What is in these roots? What will the plant do with it if it is allowed to go on growing?

Fig. 348. Test-tubes are useful for preserving long specimens. Use a *thin* cork and cover with sealing wax.

Uses of roots to the plant.— What is the first and most important use of the root to the plant? Think of the sprouting seed and its primary root. The young plant beginning to grow needs water, and the root is able to obtain this water by absorbing it from the soil.

Dissolved in the soil water, there are very small amounts of salts and other minerals. The plant needs these salts as well as water. The first use of the root, then, is *to absorb soil water and the minerals dissolved in it.*


Fig. 350. Tuberous root. This is branched like a fibrous root but has food stored in it.

Now, think of the young plant after it has sent up a stem and leaves, or of a wheat plant when it has a tall stem with a large head of grains upon it (Fig. 351). What work has the root to do at this stage besides furnishing the plant with water and minerals? Does the stem need to be held upright? If the seed grows to be a tall tree (Fig. 352), does the root require much strength to hold the tree in the *upright position*? Does a telephone pole require as strong anchorage as the tree from which it was cut? Since this tree was probably three times as tall as the pole, the pressure of the wind on its topmost branches must have caused a great strain upon the roots. In some plants special roots grow from the stem and reach downward into the ground, giving firmer anchorage. Bring into the classroom for the school collection a stem of corn showing these anchorage roots (Fig 353).


Fig. 351. Wheat and other grasses are very tall and slender. They carry heavy grains in the head. Do they need firm root - anchors to hold them upright?


Fig. 352. Which would be more strained by a strong wind? What holds the tree upright? Look for an uprooted tree to see its great net-work of fine rootlets and root fibres.

A few plants do not stand erect. In such cases, the roots, although they do not anchor the plants in an upright position, nevertheless anchor them in place so that they are not blown away by the wind or washed away by water. In some of these plants, roots grow out along the sides of the stem, and by them the plant is anchored to a wall, to another plant, or to some other support (Fig. 354). The second use of roots is *to anchor the plant.*

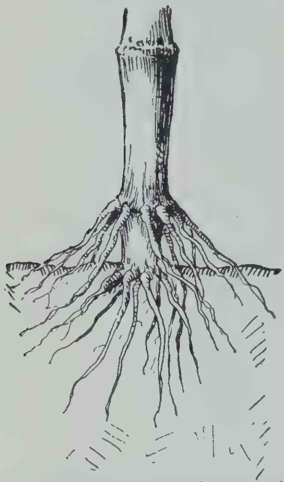


Fig. 353. The corn plant sends out special prop roots from the first node. Do they help to anchor the plant in the upright position?

The third use of certain roots we have already mentioned, namely the *storing of food.* What use is made of the food stored over winter? The plant does not use its food during the winter, as a squirrel or gopher uses its store of nuts or grain, but keeps it until the spring, when it uses it to grow new leaves that can make more food. When much food is stored, the root becomes thickened or fleshy. Name plants whose roots are fleshy. The food stored in roots is usually starch. A few roots store their food in the form of sugar. We often take the plant's store of food and use it for ourselves. We use, for example, the starchy roots of carrot and turnip, tapioca made from the starch of a Brazilian root called cassava, and sugar from the root of the sugar beet.

Fig. 354. The ivy has roots along the sides of its stem, that anchor it to the wall.

Question Outline

(1) What is the first sprout that comes out of a seed? (2) Draw diagrams from your specimens of tap root, fibrous root, and tuberous root. (3) What are the uses of roots to a plant? (4) What stored foods do we obtain from roots?

CHAPTER XLV

STEMS AND THEIR USES

Why plants need stems.—Some plants are able to live very well with no stem, or only a very short one; others have very tall stems. Can you suggest why plants need stems between their roots and their leaves or flowers?

Look at a dandelion plant. If it is surrounded by very short grass, the flowers are on very short stalks close to the ground with the leaves. Can the insects see the flowers easily? If the grass has grown up around the plant, the flower stalks grow longer and raise the flowers above the grass. What advantage does this give the flowers? One use of stems seems to be *to raise the flowers up so that they can better be seen by insects* that will carry their pollen.[1]

When the seeds of the dandelion are ripe, the flower stalks reach up higher still. Each dandelion seed, you will remember, is contained in a tiny pod with a tuft of bristles attached to it. What advantage, do you think, is gained by lifting the ripe fruits well above the grass and other plants? Will they be caught more readily by the wind? A second use of stems seems to be *to hold the ripened fruits and seeds high enough to be caught by the wind.*

Do the leaves of plants ever need to be held high up from the ground? The dandelion has no stem to lift up its leaves, but, in spite of this fact, in short grass it thrives. It cannot grow well, however, in tall grass, or among other thick and bushy neighbors. It grows well on a close-cut lawn but not

[1]Some flowers, e.g., corn, depend upon the wind, not upon insects, to carry their pollen. These usually have stems that hold their flowers *exposed to the wind.*

so well in the fields. Plants that have no stem, or a very short stem, succeed only among neighbors that are short like themselves.

The leaves of the dandelion grow directly from the top or crown of the root, but there are many kinds of plants that have their leaves supported on tall stems. What advantages have the tall-stemmed plants? Are they able to reach up and spread their leaves to the sunlight, even when they are crowded by their neighbors? Can the sun shine down between the leaves? The trees are taller than all other plants, and they spread out a great canopy of leaves to the sunlight. This third use of stems, *to hold the leaves exposed to the sunlight,* is probably their most important use.

Fig. 355. Twining stem and tendril climber. These stems are too slender to stand alone. They obtain help from other plants.

There are some plants whose stems grow long but are very thin and not sufficiently stiff to stand alone. Some of these are able to cling for support to other plants, or to rocks, or to the walls of buildings. In this way they succeed in holding up their flowers to the view of insects, their seeds to the wind, and their leaves to the sunshine (Fig. 355).

Some stems can neither stand alone nor climb, those of the strawberry and the silverweed, for example. These lie flat along the surface of the ground. The branches grow outward in different directions from the root, sometimes on the surface of the ground and sometimes underground. As they grow longer, they take root here and there (Fig. 356).

In this way new plants are started by the stem, instead of by means of flowers and seeds. This fourth use, *starting new plants*, is served by the stems of only a few plants.[1]

Fig. 356. Creeping stems do not hold their leaves and flowers high. They have a different use. What is it?

A few plants have underground stems in which they store food. The potato (Fig. 357) stores a large quantity of food in its under ground stems or "tubers"; the sow-thistle stores a smaller quantity. This fifth use of stems, *storing food*, occurs, like the previous one, in only a few plants.

We cannot see what is going on inside the stem of a plant, but we know that the soil water that is absorbed by the roots moves upward through tiny sap tubes[2] in the stem until it reaches the leaves and flowers. We also know that the sugary sap made in the leaves is carried downward through sap tubes in the stem. *Carrying sap upward and downward* is therefore a sixth use of stems. It is necessary only because the stem separates the leaves and flowers from the root. The shorter the stem, the more readily the sap travels from one part of the plant to the other.

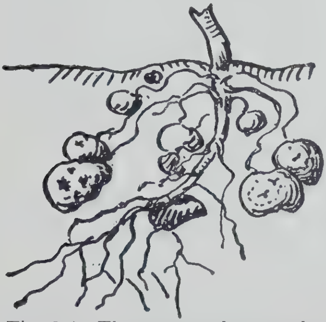


Fig. 357. The potato plant sends out some stem branches that go down underground. The ends of these store food and become tubers. Notice that the potatoes do not grow on the roots.

The hollow "straw" stems of grasses.[3]—Examine the stem of a

[1]The starting of new plants from cuttings is an artificial method of making upright stems start new plants, as trailing stems and underground stems naturally do (see page 387).

[2]The sap tubes may be seen in the end of a piece of cane or of new oak wood. Try blowing through them into water. Dried willow and elm roots, often found uncovered along the river bank, or a piece of bittersweet stem will serve the purpose, though in these the tubes are almost too small to be seen except with a magnifying glass.

[3]For this lesson bring into the classroom stems of grasses and cultivated grains,—one or more for each pupil.

grass plant, and of a cultivated grain, such as wheat or barley. We call these stems of grains and grasses *straws.* What are they like? First, we notice that they are smooth and round. Can you find the solid joints, or **nodes.** There are several in each stem. If you find a grass stem that has been trampled down flat upon the ground, you will see that these nodes bend upward, so as to raise the stem again into the upright position (Fig. 358). The lower part of each leaf is wrapped tightly around the stem. If we strip off a leaf, we shall find that it grew out from the stem at a node. Have you ever pulled out the top section of a green stem of sweet grass, wheat, or oats from its leaf sheath to taste the sugary sap in the soft growing end? The leaf sheath supports this soft growing part until it becomes strong.

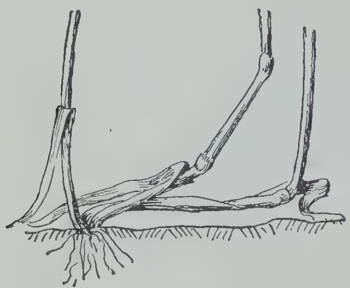


Fig. 358. When a grass stem is broken down, it rises again by bending at the nodes.

The parts of the stem between the nodes are called the **internodes.** In most grasses they are hollow. Can you think why this is an advantage to the plant? It can obtain only a small amount of food, and with this it must make a stem that is as tall as possible and yet strong enough to hold up its head of grains. With its scanty supply of food, the stem can grow taller if it is hollow, than if it grows solid. Compare the height and thickness of the stem.

Do these grass stems produce branches above their lowest joint, or node? Stems that are without branches are called **simple stems;** all others are **branched stems.** The corn plant and the sugar cane are very large grasses, and their stems show the nodes and leaf sheaths very plainly. Bamboo is another giant grass. Can you see its nodes? Is its stem very strong for its size?

The stems of shrubs and trees.—There are many tall-stemmed plants, such as the thistles and the mustards, but the tallest of all the plants are the trees. Why are the trees able to grow so much taller than the thistles? It is because they are *woody plants*, and their stems are so tough and strong that they are able to survive the winter and continue growing the next year. The thistles and the mustards are soft-stemmed or *herbaceous plants*, and their stems die every fall. Because of this they can never become very large.

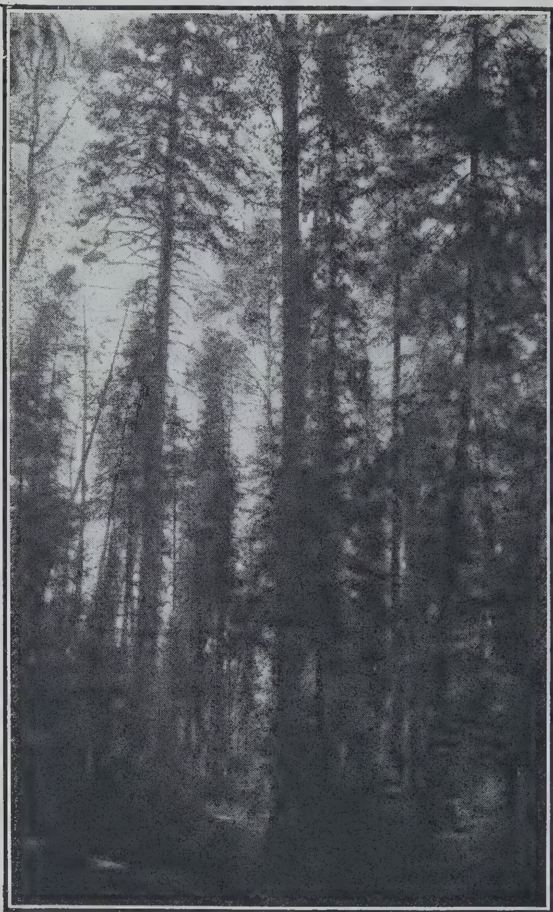
Fig. 359. The snowberry is one of our commonest roadside shrubs.

Fig. 360. A shrub is a woody perennial plant smaller than a tree and having a number of stems.

There are many kinds of woody plants. Some, such as the rose bushes, spirea, and the little roadside snowberry (Fig. 359), are not very large. Others, like the lilac, dogwood, hawthorn, and silverberry, are larger, but they are not as large as trees. All of these are woody plants with several stems and many branches (Fig. 360). Plants of this kind are called **shrubs**. The larger woody plants, which have one main stem, we call **trees**.

Fig. 361. Bur oak in winter condition. Does the main stem "run out" at the top?

You have seen trees of many kinds and many different shapes. In fact, when you see them in the distance, during the winter, when they are stripped of their leaves, you can name some kinds from their shapes. In some, the main stem divides into a few large branches about equal in size, making a round-topped tree, like the elm (Fig. 37). In others, the main stem runs out at the top, and the branches are smaller than the stem, as in the ash, the oak (Fig. 361), and the spruce (Fig. 37). This forms a pointed top that makes these trees appear quite different from the round-topped kinds. The trees whose stems run out at the top are said to have *excurrent trunks* (*ex*, out, *curro*, I run). Compare the two trees in Figure 37.



Courtesy Forest Service, Ottawa

Fig. 362. Excurrent trees growing very close together in a forest. Would these make good telephone poles and good lumber? The spruce tree in the middle is 22 inches thick at a height of 4 feet from the ground. It is 130 feet high and 175 years old.

When excurrent trees grow in a dense forest (Fig. 362),

their lower branches are so shaded that they die while they are still small. The young branches at the top and the top twig of the stem receive nearly all the food and therefore grow rapidly. As a result, the tree comes to have a very long, slender stem. Such trees, because they are very straight and have no large branches to form knots, are especially suitable for making telephone poles, or for sawing into lumber. In dense forests there are not only more trees but also better trees for making lumber and poles than in the less thickly wooded regions.

How people make use of the stems of plants.—We have only to think of our need of food, clothing, and shelter, to think of ways in which we make use of stems. For *food* we use the stems of asparagus and sago, and the underground stems of potato. For *clothing* we use linen made from the stems of flax, and for *shelter*, or houses, we use the stems of many kinds of trees hewn into logs or sawn into lumber. You can suggest the names of plant stems that serve for *fuel* and many other uses. Then, if you think of the people of other lands, other uses to which they put stems will suggest themselves to you. Refer to the lists that you made in Chapter I showing the uses of plants to people, and pick out the ones in which the stem of the plant is used. Do you see that the stems used by trees for supporting their heavy tops are often used by us for supporting bridges, roads, buildings, and other heavy loads? The stems in which plants store food we also use as a store of food.

Question Outline

(1) Make a list of the uses of stems to plants. (2) In which of these ways does the golden-rod use its stem? the maple tree? (3) What stems do you know that climb? (4) Which of them are twiners? Which of them hold on by tendrils, like the Virginia creeper (Fig. 355)? How does the ivy

climb (Fig. 354)? (5) What special use have the stems of strawberry and silverweed (Fig. 356)? (6) Part of the potato stem is underground. What is its use? What does the part above the ground do? (7) Draw a diagram of a piece of grass stem, showing a node and a leaf sheath, as well as the internode. (8) Mention two uses of the nodes. (9) What advantages does the plant gain by growing a hollow stem? (10) What are simple stems? (11) How can you distinguish shrubs from trees? (12) What are *herbs*? (13) Draw diagrams in your note-book showing the two types of branching of round-topped and pointed-topped trees that grow in your district. Give their names. (14) What is the usual shape of trees in a dense forest? (15) For good poles or lumber, should new forests be planted close or open? (16) Make a list of the uses to which we put stems. Add to it whenever you hear of new examples.

CHAPTER XLVI

LEAVES AND THEIR USES

Preparation.—For this lesson each member of the class should bring into the classroom a fresh green leaf. Choose a kind in which the veins can readily be seen. One large rhubarb leaf makes a good demonstration specimen.

Leaves make food for the whole plant.—We cannot see what is happening inside a leaf, but if we could, we should see some very interesting things. Tiny streams of water are constantly coming up from the roots through the sap tubes of the stem (see page 413). These flow along the **veins** all through the thin, flat part of the leaf. Notice on your specimen how the veins branch out from the leaf stalk, or **petiole,** to all parts of the **blade** of the leaf (Fig. 363). Besides the *water*, which the veins bring to it, the leaf takes in some of the *air* that people and animals breathe out; and the green substance of the leaf, called **chlorophyll,** joins the water and the air together to make sugary sap. It can make this very wonderful change only when it is receiving *light*. It is easy, therefore, to understand why leaves need plenty of sunshine. With the help of sunshine they make food for the whole plant.

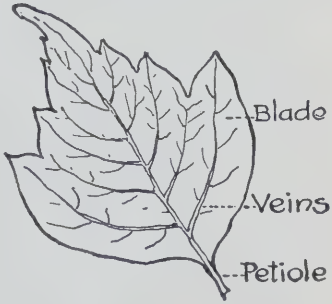


Fig. 363. The important parts of a leaf are the blade (containing chlorophyll), the veins, and the petiole or leaf stalk. Find these on your specimen.

What becomes of the food made by leaves?—The leaf itself uses some of the food that it makes and thereby grows larger. Some of the food goes down to the root, which

also grows larger and collects more soil water. Some is used by the stem, and some goes up to the buds to make flowers. A great deal of it is used in making the store of food for the tiny young plants in the seeds. Could a plant make flowers or seeds if its leaves were cut off or badly damaged by insects or disease? It is clear that every part of the plant depends upon the leaves for food.

How people and animals depend upon the food made by leaves.—The sugary sap is very important to us, as well as to the plant. Sometimes we use it directly for food, as in maple syrup and molasses (see page 377). Sometimes we eat the parts of the plant that have grown from the sap, for example, the root of the carrot, the fruit of the apple tree, or bread made from the seeds of wheat. In these cases the sugar has been changed to starch and stored, but it is still the same food, manufactured by the green leaves.

Animals also eat the leaves, stems, and other parts which the plant has made from the sugary sap. From these animals we obtain the rest of our foods: eggs from birds; milk, cheese, and other foods from cows; and meat from many kinds of animals.

Can we not say, then, that the green leaves of plants provide us directly or indirectly with all our food? They make sugary sap from the soil water and air, and with it they feed the plants. Then we eat the plants, or we feed the plants to animals and obtain our food from the animals. With the exception of water and a very little salt which we take from the earth, we obtain all our food from green leaves.

Not only do green leaves provide us with food, but they provide us indirectly with clothing, shelter, fuel, and many other things, since they manufacture most of the food for the growth of the plants from which these things are made. There are few necessities that we possess that we do not receive from the green leaves of plants.

How do the leaves perform their useful work?—We have seen that the leaves of green plants perform a great deal of useful work and manufacture a large quantity of useful material. We also know that, to do work, they must receive strength or energy from light. Let us now try to discover, by means of two experiments, what the leaves do and how they do it.

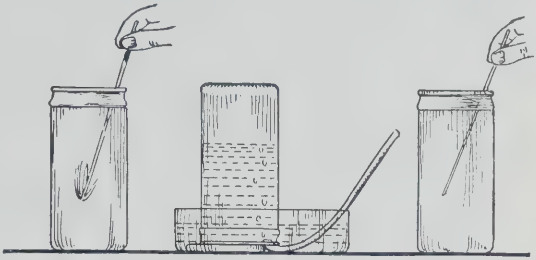


Fig. 364. A, Fresh air supports burning. B, Collecting a jar of breathed air. C, Breathed air does not support burning.

Experiment I

Object.—To discover the effect of leaves upon air that has been breathed.

Apparatus.—Two quart sealers ("Victory" pattern preferred), two shallow dishes (e.g. soup plates), a splinter of wood or a match on a wire handle, a rubber tube as shown in the diagram (Fig. 364), a cutting from a plant with healthy leaves (about eight square inches of leaf area).

Method.—Test fresh air in a jar, as at A (Fig. 364), to show that it supports burning. Collect, as at B, a jar of breathed air that has been held in the lungs for some time. Test this breathed air, as at C, to show that *breathed air does not support burning.*

Now fill two jars with breathed air, as at A and B (Fig. 365), having first placed in B the cutting from a plant. Leave half an inch of water in the jar so that the stem will dip into it. Place these two jars in bright sunlight for several hours, or leave them in the light for a day or two. (Covers and rubber rings are in place.)

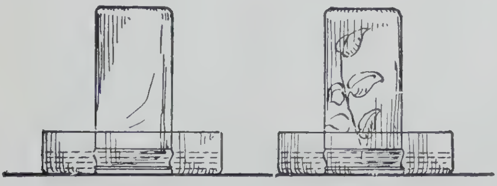


Fig. 365. A, Breathed air exposed to sunlight. B, Breathed air with leaves exposed to sunlight.

When the leaves have had several hours' sunlight, invert A, keeping it covered. Test this breathed air, as you did in C, to show that it has not been changed by the sunlight. Now test the air in B to see whether it has been changed.

Observations.—(1) Does breathed air support burning even when exposed to sunlight? (2) Has the breathed air of jar B been changed by the leaves? (3) What change has taken place?

Conclusions.—(1) What effect have the leaves of plants upon breathed air when they receive sunlight? (2) May we say that *green leaves* in sunlight change "breathed" air back to fresh air?

From this experiment we understand how plants help to "purify the air" for us to breathe.

If a similar experiment is performed with the jars in darkness, you will find that the air in B is not changed by the leaves. This shows that leaves purify the air *only* when they have light.

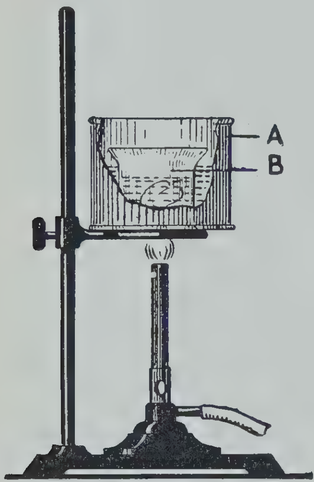


Fig. 366. Removing the green chlorophyll from leaves so that they may be tested for starch. Vessel A should be much larger than vessel B, so that vapor of methyl hydrate will not come near the flame.

Experiment II

Object.—To discover whether leaves must have sunlight in order to manufacture food.

Apparatus and materials.—A water bath, a burner, two plants, starch, iodine solution,[1] methyl hydrate.

Method.—Obtain two similar plants. Slips of geranium, coleus ("foliage"), or begonia, growing either in water or in soil, will do. Place one in darkness and keep the other in a sunny place for two days. (Perform the experiment after several hours of sunlight.)

Allow a drop of iodine solution to fall upon some starch so that you will know the effect of iodine upon starch.

Take one leaf from each plant. Mark the one that was in sunlight with a piece of thread. Wash out their chlorophyll as follows: Dip them into boiling water in the metal vessel[2] shown at A (Fig. 366) for one minute or until they are limp. Shake out the water and place them in the metal or *thin* glass vessel (B) containing methyl hydrate. If the vessel is of glass, it should be placed in the boiling water carefully to avoid cracking. Remove the flame, or turn it low, as the methyl hydrate will boil at a lower temperature than the water. Boil the leaves in the methyl hydrate until nearly white. It

[1]This may be iodine dissolved in a weak solution of potassium iodide or in alcohol (tincture of iodine).

[2]For safety in case the fumes are ignited from the burner.

may be necessary to use a second or even a third lot of the liquid if there is much green chlorophyll in the leaves.

Dip the leaves in boiling water again to make them soft, shake off the water, and then spread them out on a piece of glass or paper. Moisten them with iodine solution and leave them to soak for a time.

Observations.—(1) Does either of these leaves show any of the bluish black color that we obtained when we put iodine on starch? (2) Which leaf has starch in it?

Conclusions.—(1) Can leaves make starch (food) in the dark? (2) Must leaves have sunlight in order to enable them to do the work of making starch? As heat from a fire gives a locomotive engine strength or energy, so light from the sun gives the leaves energy with which to do their work.

From Experiment I we learned that leaves, when they are in sunlight, change breathed air back to fresh air that will support burning. From your study of carbon dioxide (Chapter XLI) you will know that breathed air contains more carbon dioxide and less oxygen than fresh air. In changing it back to fresh air, therefore, *the leaves must have used up carbon dioxide and given out oxygen.*

From Experiment II we learned that leaves make starch when they are in sunlight. This starch is changed to sugar and, as we learned in Chapter XLVI, is carried in the sap to all parts of the plant, where it is used to grow new wood, cork and other substances that are required by the plant.

Green leaves are able to give off oxygen and make the air fresh. Plants that are not green, however (for example, mushrooms and the young plant in a pea seed), are not able to do this. The experiment illustrated by Figure 167 made it clear that young plants without green leaves must have fresh air (that is, air with plenty of oxygen in it) in order to grow. The plants that have green leaves also need oxygen, but they are able to set free more oxygen in the day time than they need during the day and the night.

Question Outline

(1) What comes into the leaves from the roots of a plant? (2) How does it reach the leaves? (3) What else does the leaf take in, and what use does it make of the two substances? (4) What part in the leaf does the work of making food? What help must it have to do this work? (5) What kind of food does it make? (6) What becomes of the food made by the leaves? (7) How can it be said that we are using food made by leaves when we drink milk, eat candy, or eat bread? (8) How can we show that leaves change breathed air to fresh air? (9) Are forests of use to us in this way? (10) Do leaves carry on this work at night? (11) How can we show that leaves need sunlight in order to enable them to make food for themselves and for us? (12) What use do plants make of the foods that they manufacture? (13) Where do leaves obtain the strength or energy that enables them to manufacture starch?

PART V

SPRING STUDIES OF ANIMAL LIFE

CHAPTER XLVII

FROGS AND TOADS

Introduction.—Who has not been delighted in early spring to hear the first musical notes from the ponds and streams, the song of the frogs and toads? These cheery little animals may be found in any pond, ditch, or quiet shallow river margin where water is likely to remain for a few weeks in the spring. Where do they come from? Are they found only in the water? What is their life history? Do they sing all summer? Are they of any value to us? These and many other interesting questions come to our minds in April and early May, when the welcome chorus of frogs and toads tells us that spring is here.

Preparation and materials.—In ponds or ditches where you hear frogs "singing," look for a thick jelly-like mass of eggs a little below the surface of the water, usually adhering to grass or sticks. The cluster of eggs will be almost large enough to fill your hand, and may remind you of boiled tapioca. Put a cluster of these eggs in a pail or jar together with some of the water in which you find them and a little pond scum or a few pieces of grass or sticks found in the water. Bring them to the classroom, and place the eggs and the pond water in a wide shallow dish or pan. Shade them from direct sunlight. Keep them thus until required, removing any that die and turn white.

For each pupil or for each small group of pupils clip a few eggs from the cluster with scissors and put them in a quart or pint sealer. If too many are put in one jar, they will soon die because they will use up the oxygen that is dissolved in the water. Nearly fill each sealer with pond

water. If pond water is difficult to obtain, put only a little of it in each sealer and nearly fill the jar with rain water. For food add a little of the pond scum or a few pieces of grass or sticks brought from the pond. Some cf the eggs may be put into the school aquarium. If there are fish in the aquarium, put in a partition of glass, wood, or wire screen so that the fish will not devour the eggs and tadpoles (see Fig. 378).

For the school collection put a few of the eggs in a small bottle and preserve them in 5 per cent formalin. For class study at a future date a whole cluster may be preserved in this way.

To obtain a collection of specimens showing the life history, or story of a toad or frog from the egg to the adult form, as shown in Figure 367 or Figure 368, take specimens from your sealers or from your aquarium as your frogs or toads develop and preserve them in formalin or methyl hydrate.

To examine the adult frog or toad, capture one without injuring it and bring it to the classroom. Place it in a cage like the one shown in Figure 70 or a similar cage made of screen with quarter-inch mesh.

Make a hole about as large as a cup in the turf and keep it full of water. While kept in the cages the frogs or toads may be fed upon living insects such as flies, or upon worms, or upon larder beetles raised for this purpose (see Appendix, Sec. 26).

After you have placed the eggs in the sealers for study, make daily observations and notes upon the changes that occur in the shape of the black spot in each egg until the tiny tadpole leaves the jelly.

The eggs of the frog or toad.—The female frog lays her eggs in shallow cold water shortly after the ice is gone. Toads commence laying their eggs about two weeks later than frogs. Various kinds of frogs lay various numbers of eggs ranging from several hundred up to three or four thousand. Toads may lay as many as 10,000 or more. You may be able to estimate approximately the number of eggs in the mass brought into the classroom.

You have examined the small mass of eggs in your sealer. Were they in strings as shown in Figure 367 or in an irregular cluster as shown in Figure 368, A? The frog lays its eggs in an irregular cluster, each egg surrounded by a sphere of clear jelly. The toad lays its eggs in strings of clear jelly. Within

the body of the frog and the toad this jelly occupies very little space, but in the water it swells up and forms a thick coating over the eggs (Fig. 368, B). Do you think it may help them to float?

What is the shape of each egg within the jelly at first? What is its color? Which tends to warm up more quickly, a dark surface or a light shiny one? (See page 183.) Will color be an advantage in hatching the egg quickly? Is each egg the same color above and below? If you have the eggs of a toad, they will be black on top, but lighter below. Do not mistake for toads' eggs frogs' eggs that have

Fig. 367. Life history of the toad. Describe the various stages.

died. They turn light gray all over and should be removed immediately to prevent decay.

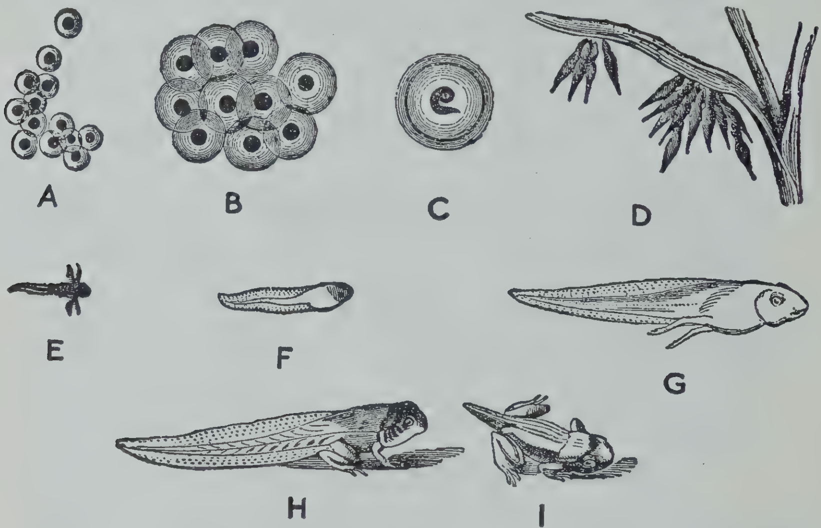
As the eggs develop, what change in shape occurs? Do you notice any movement within the jelly? How long did it take these eggs to hatch into tiny animals that wriggled away from the jelly? Where did they go (Fig. 368, D)?

The tadpole stage.—The tiny animal that hatches from the egg is called a tadpole. What is the shape of its body?

For the first day or two the young tadpole usually attaches itself by a sticky substance on the under side of the head to an object such as a blade of grass. It may, however, settle to the bottom of the body of water in which it hatched. During this *inactive tadpole* stage it lives on

some of the yolk of the egg enclosed in its body, and breathes through its skin. At the end of a day or two the tadpole begins to swim about actively.

Now look for the feather-like gills growing out on each side just behind the head (see Fig. 368, E). How many are there? Watch them from day to day to see when they disappear. Does the tadpole at this stage look at all like a fish?



After Brehm.

Fig. 368. Stages in the life history of the frog. A, Eggs before they are laid B, Eggs after they are laid in the water. C, Egg magnified to show the tadpole hatching. D, Young tadpoles attached to a blade of grass. E, Young tadpole showing external gills. F, Young tadpole. Its external gills have been replaced by internal gills. G, Tadpole with hind legs appearing. H, Tadpole with large tail and front pair of legs now appearing. I, Very young frog. It breathes by lungs. The tail is being gradually absorbed by the blood and carried to other parts of the body for food.

In these gills are many tiny blood vessels with thin walls. The oxygen of the air dissolved in the water enters the blood through these thin walls. At the same time carbon dioxide (see page 370) is breathed out from the blood into the water.

In a few days these outside or *external gills* disappear. Meanwhile new gills have been forming inside the head. These *internal gills* now take the place of the external

ones. Find on one of the tadpoles a tiny opening on the left side of the head, and also a mouth. Water containing air passes through the mouth of the tadpole, washes over the internal gills, and passes out through the opening on the side of the head. The tadpole now breathes like a fish. Look for the openings on each side of the head of a fish in the school aquarium. Inside these openings are the feathery gills. Find them in the head of a fish that has been caught for food. (There should be a preserved fish in your school collection.) Water enters the mouth of a fish, and passes over the gills and out through these openings as it does in a tadpole.

What is the shape of the tadpoles that are now swimming about? Watch them feeding upon the microscopic plants growing on the inside of the glass. You can see the mouth quite easily in the larger tadpoles. Has the tadpole eyes?

Note-book record.—Divide a page of your note-book into six equal parts and number them. In the first part draw a cluster of eggs and record the date on which they were found. In the second space make a diagram of the very young tadpole with external gills. In the third space make a diagram of the young tadpole that now seems to be all head and tail.

The tadpoles of some frogs take from eight to ten weeks to develop into small adults. Others, for example the tadpoles of green frogs and bullfrogs, do not become adults until the following year. The large tadpoles sold by dealers may take several years to develop. Toads usually develop in about eight weeks. As it takes a long time for a tadpole to grow into a frog, further study and note-book work can be done by observing the tadpole develop from week to week and making diagrams.

In the fourth space on the page of drawings of the frog, make a diagram of the animal when the hind legs appear. Record under it the date. Again when the front legs appear, make a diagram in the fifth space and record the date.

NOTE.—As soon as the tadpole gets its legs, observe whether it comes to the surface from time to time to breathe. Watch for a change in the appearance of the tail.

Adult frog or toad.—Observations on the development of the tadpole will extend over several weeks. Meanwhile

let us study an adult frog or toad that has been secured from a pond and placed in a cage.

What is the color of the animal? What is its covering? Is the skin smooth, or is it rough as if covered with little lumps that, in their general appearance, resemble warts.

From Dickerson's "Frog Book" by courtesy Doubleday, Page & Co.

Fig. 369. Leopard frog. Do the markings on this frog make it appear like its surroundings?

If your specimen is a frog, it will have a smooth skin. Would the green color on the skin make it difficult to see the frog when it was among green plants? Would its brown shades match the color of soil and dead leaves? In its natural surroundings, would the black blotches or spots look like shadows (Fig. 369)? Would these colors help to protect it from birds, such as the crow and the bittern, and from snakes? Because the frog looks so much like its surroundings, you may have had some difficulty in finding one for study. What is the color of the under side of the frog? If a frog were floating in water, would it be difficult for a fish to see the pale under surface of the body, which appears so like the light sky above? Did you discover that the skin of your frog is moist and slippery? You may have found it difficult to retain your hold upon it when you caught it. What would be the advantage to the frog of such smoothness?

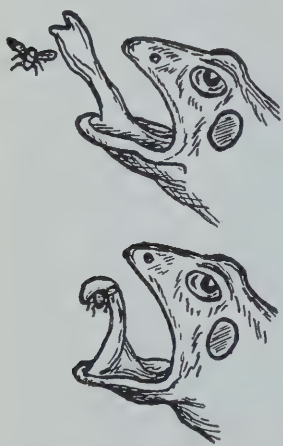
If your specimen is a toad, it will be shaped somewhat like a frog but will have a dark, rough, warty skin (Fig. 370). You will not get warts by handling a toad. Where did you find the toad? In the evening look for one in a garden, in a cultivated field, or in the woods. If you live in the city, you may find one at night under a street light, where it is probably catching insects that have been attracted by the bright light.

Does a toad appear somewhat like a lump of earth in a garden? Would this resemblance make it difficult for its many enemies to find it? Some toads and frogs live in trees, where they find protection because their markings and color resemble those of the bark and the leaves.

Courtesy American Museum of Natural History.
Fig. 370. Toad. Does the rough "warty" skin of the toad resemble the lumpy ground on which it is often found? Of what advantage is this to the toad?

Are frogs and toads of value to us?—Most frogs never wander far from the water. They live on insects such as mosquitoes, mayflies ("fish-flies"), and other insects found flying about the shore, and on grasshoppers, crickets, beetles, and spiders in the meadows near by. Toads, on the other hand, leave the pond when young and may not return to it for three or four years. During this time they are busy all summer long ridding our gardens and fields of numerous insect pests such as cutworms, grasshoppers, and beetles, and helping to destroy flies and mosquitoes. We see, then, that frogs and toads are very helpful to us, and we should therefore protect them.

How does the frog or toad catch insects?—Is the mouth of the frog or the toad large or small? Watch it catch a fly, a grasshopper, or some other insect that you put in the cage. Can you see the tongue flip out of its mouth and in again when it catches the passing insect? The movement of the tongue is so rapid that it will be necessary for you to watch closely to see what happens. Its tongue, which is sticky, is fastened to the front part of its mouth, the tip pointing back towards the throat. (Where is your tongue attached?) To catch an insect the tongue is thrown outward to full length, as shown in Figure 371.



From "Zoology for High Schools" by Calvert and Cameron.
Fig. 371. Frog catching an insect with its sticky tongue.

Does the frog or the toad jump at the insects in the cage or wait until they pass close by to catch them? You may answer this question by putting several insects in the cage, and leaving the animal undisturbed. Watch its movements closely and observe the sudden disappearance of the insects. Since frogs and toads resemble their surroundings, are insects apt to fly close to them without being aware of danger? Does their color therefore aid them in securing food? Are different specimens alike in color?

How does a frog or a toad travel about?—How does a frog or a toad move about on land? Which pair of legs is used in hopping? Which pair is the longer? How far can these animals hop? Which can hop farther, a frog or a toad? Do the hind legs appear strong? When the animal is resting, are its feet in position ready to spring? Would this help it to escape from an enemy that came upon it suddenly? Are its feet webbed? Has it claws?

Put a frog or a toad in water in a large vessel and watch it swim. How does it move its front legs when swimming? When it straightens its hind legs out, does it somewhat resemble a fish in shape?

How frogs and toads escape from their enemies.— Most frogs live in or about water. At the first sign of danger a frog dives into the water with a splash. Its large webbed feet, muscular legs, pointed head, and slippery

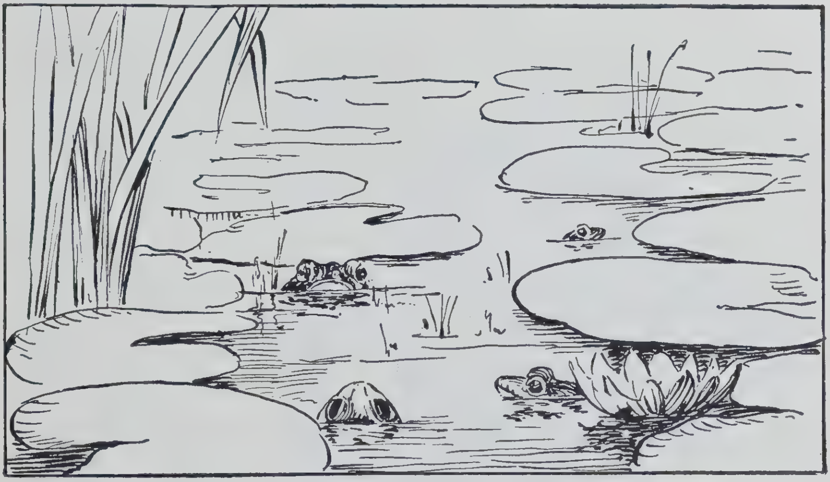


Fig. 372. Frogs among lily pads. Why do frogs come to the top of the water? Why is it difficult to see them when they come to the surface? Of what advantage to the frog is the large pair of eyes?

skin enable it to swim quickly to the bottom, where it stirs up the mud. Could an enemy easily follow and catch it? After the first splash, all the frogs along the shore dive to safety, but, unless danger follows, they soon come to the surface to look about and to breathe (Fig. 372).

When surprised by a snake or other enemy, a frog may suddenly straighten its four legs and puff out its body. This makes it more difficult for the snake to swallow the frog, which may thus escape death. Have frogs or toads any means of defending themselves against their enemies?

In the spring, when you approach a pond where frogs are singing, their chorus ceases. Why? After you have waited very quietly for a short time, the frogs will come to the surface. You will not see them, however, unless you look very closely, because they come up near the blades of grass, and only their eyes and nostrils show above the surface of the water. In this position they can watch you and your doings quite comfortably. To see them, therefore, look for a pair of eyes rather than for the whole frog (Fig. 372). If you remain motionless for some time, they may commence to sing again. Watch their throats swell out as their voices become louder. If it is not too frightened, a frog in a cage will sing when you gently stroke its sides with a feather.

From Dickerson's "Frog Book" by courtesy Doubleday, Page & Co.

Fig. 373. Toad singing.

Unlike most frogs, toads seldom go to the water. Their feet are not so well webbed as those of frogs, and they cannot therefore swim as rapidly. When danger threatens, they seek refuge by crawling into dark places or by burying themselves in loose dusty earth. A toad partly buried in the garden so closely resembles a lump of earth that it can be seen only with difficulty. Place a toad in dry earth and see how quickly it can bury itself.

Note-book Record.—In the last space left for drawings of the tadpole and frog, make a diagram of the hind legs showing the webbed feet.

How do frogs or toads breathe?—We have seen that the tadpole breathes by gills which enable it to obtain air from the water. Like fish, which also breathe with gills, tadpoles will die if kept out of water very long. Adult toads and frogs, however, can live out of water. During the last stages in the development of tadpoles, lungs are formed, which enable them to breathe air. Watch tadpoles which have developed their four legs, but still have their large tails, or are just losing them, and notice that they come to the surface from time to time. The lungs in these animals consist of a large pair of sacs within the body.

Watch the throat of a frog or a toad as it moves in and out drawing air through its nostrils and forcing it down into its lungs. Notice the sides of its body moving as it breathes. Does it need to push its whole head out of the water in order to breathe? What is the advantage of having the nostrils on the top of the snout, and the eyes protruding from the top of the head?

Is the body of a frog or toad warmer or colder than its surroundings?—You have probably heard it said that some animals are "cold-blooded." What is meant by this? When you pick up a frog or toad, does it feel warm or cold to your hands? How cold is it?

Experiment

Object.—To discover whether the body of a frog or a toad is warmer or colder than the air or water around it.

Apparatus.—Two beakers, each large enough to allow a hand to be placed in it, two thermometers, enough water at room temperature to half fill each beaker, a frog.

Method.—Half fill the two beakers with water that has been standing in the room for some time, so that it will be at the same temperature as the air in the room. Put a thermometer in each beaker and record the temperature. Now put your hand into the water in one beaker and put a frog in the other beaker. Leave each in the water for about fifteen minutes. Watch for any change in the temperature of the water.

Observations.—(1) Does the temperature of the water into which you put your hand rise or fall? (2) Does the temperature of the water into which you put the frog change? If so, by how many degrees?

Conclusions.—If your hand is warmer than the water in the beaker, heat will leave your hand and go into the water. This will heat the water. Did this occur? Is the temperature of your body considerably higher than the temperature of the water in the room? Is your body temperature higher than that of its surroundings?

Similarly, if the frog were warmer than the water in the beaker, heat would leave the body of the frog and go into the water. This would heat up the water. Did this occur? Is the temperature of the frog, therefore, about the same as the temperature of the water? Is its body at about the same temperature as its surroundings?

Animals whose bodies are kept warm in both hot and cold surroundings are called **warm-blooded animals.** The temperature of warm-blooded animals remains almost the same whether the temperature of their surroundings is high or low. Our body temperature remains at about 98.6° F. in summer and in winter, indoors and out. Is a bird warm-blooded? Hold a bird or a barnyard fowl by the body and notice how warm it feels. The body temperature of a bird is even higher than our own. We all know that cats and dogs are warm-blooded. Indeed, all animals covered with hair or fur are warm-blooded. These animals feed their young with milk and are for that reason called "mammals."

Toads and frogs, on the other hand, have a body temperature which is about the same as the temperature of their surroundings. When their surroundings, such as air and water, become warmer, their bodies become warmer also. And when the temperature of their surroundings becomes lower, their body temperature lowers also. Animals whose bodies become warmer or colder as the temperature of their surroundings changes, are called **cold-blooded animals.**

When, in the autumn, the weather becomes cold, frogs and toads become less active. It is then that frogs prepare

for a long winter's sleep by burying themselves in the mud at the bottom of a pond or stream, or in the earth. When toads wish to make their winter beds, with their hind feet they push their way into the ground, under stones, boards, shrubbery, or dead leaves that afford some degree of protection. As a toad digs a hole, it backs into it, allowing the earth to cave in over its head. In this retreat it lies asleep throughout the long winter.

When they go to sleep in the autumn, toads and frogs have fat stored within their bodies. It is this fat that keeps them alive through the winter. They require only a little air to provide them with sufficient oxygen. This they absorb through their skin. They could not live upon this small amount of food and air if they were moving about, but it is sufficient to support life while they are asleep.

Because frogs and toads are cold-blooded, they become cold with their surroundings, so cold and stiff, in fact, that they may appear to be frozen. If, however, the blood has not been frozen, each little animal, when the warm spring days come, wakes up and finds its way out into the sunshine. Then they gather in great numbers in the ponds and streams where they lived as tadpoles, and proclaim by their musical chorus their joy at being awake again.

Question Outline

(1) When are the eggs of the frog and the toad laid? Where? (2) What do the eggs look like? Which animal lays its eggs in ribbons and which in irregular clusters? What is the color of the eggs? In what way is their color an advantage? Of what use is the jelly to the eggs? (3) Where do tadpoles go when they hatch? On what do they live for the first day or two? How do they breathe during this time? (4) What breathing organs develop in a short time on the outside of their bodies? What do they eat with their newly-formed mouths? (5) During the next few weeks of their lives how do they resemble fishes? (6) Which pair of legs appears first? How long after the appearance of the first pair of legs did the second pair

appear on your specimens? (7) In the last stage of the development of tadpoles, why do they come to the surface of the water from time to time? What happens to their large tails? Does this suggest why they cease eating at this time? (8) Where do you usually find frogs (*a*) in the spring? (*b*) in the summer? Where do you find toads in these seasons? (9) Compare the skin of the frog with that of the toad. Do the colors and markings of a frog make it resemble its surrounding? Does the toad resemble its surroundings? (10) Of what value are toads and frogs? Should they be protected? (11) How do they catch insects? To what part of the mouth is the tongue attached? Is it sticky? (12) Which pair of legs is the longer? Which is the stronger? How do these animals move on land? in water? Are both pairs of feet webbed? (13) What enemies have toads and frogs? How do they protect themselves when enemies approach? What other protection have they? (14) How does the adult frog or toad breathe in the summer? What movements can you see as it breathes? (15) Where do frogs and toads pass the winter months? How do they breathe at this time? What is their food? What would happen if a frog were very thin when it went to sleep in the autumn? (16) What is the difference between a cold-blooded and a warm-blooded animal? What animals are warm-blooded? How could you show by an experiment that the body of a toad or a frog is at about the same temperature as its surroundings?

CHAPTER XLVIII

FISH

Fish are so abundant in streams and lakes that there are few boys or girls who have never seen a fish. But, because fish live down in the water, many of us may never have had the opportunity of observing them closely as they swim about in their natural homes. We can, however, have the privilege of watching these interesting animals if we prepare a proper home for a few small fish and put some of them in it.

An aquarium (*aqua*, water).— A vessel prepared as a home for plants and animals that live in the water is called an *aquarium*. A pail with water in it, though suitable as a container for fish, would be unsatisfactory as an aquarium because it would be difficult to observe any animals placed in it. An aquarium should have walls of glass. A battery jar made of clear glass[1] or a glass pneumatic trough holding a gallon or so of water makes a small but satisfactory aquarium (Fig. 374). It is large enough to hold three or four fish about two inches long, or one or two fish three inches long. You may keep one small fish in a quart sealer if you change about half of the water every day or two and do not allow the water to become heated by the sun.[2]

Fig. 374. A simple but satisfactory aquarium.

When you have procured an aquarium, place in the

[1]Green glass battery jars are not satisfactory for use as aquaria. Clear jars may be obtained.

[2]If you wish a better aquarium, a rectangular one with glass sides and metal corners is very satisfactory. Suggestions for making one are given in the Appendix (Sec. 24).

bottom of it about two inches of clean sand.[1] To clean the sand put it in a pail, add plenty of water, and stir thoroughly. Then pour off the water. Repeat this until the water remains almost clear. While you may not be able to clean the sand completely, you will wash out much of the clay and other impurities. If the aquarium is large, do not add the sand, which is heavy, until you have placed the aquarium where you wish it to remain permanently. It may be placed directly in front of a north window, or it may be put *beside* a south window in a position that will avoid direct sunshine. Bright sunlight will warm the water too much and cause the rapid growth of tiny green plants on the inside surface of the glass.

Fig. 375. Cuttings of water plants inserted between the strands of a string to anchor them in place.

In the sand in the aquarium, plant a few water-plants. Any kind of plants that you find growing *under* water in ponds or streams,[2] or aquarium plants sold by dealers in goldfish, may be used. To hold the plants until they become rooted in the sand either weight each one down by tying a little stone to it or wrapping a little lead foil around it, or attach a number of plants to one string and hold the string down in the sand by tying a stone to each end (Fig. 375).

On top of the sand near one end of the aquarium place a flat stone. When putting water into the aquarium, pour it on this stone. If water is poured on the sand, the

[1]Gravel or small stones are quite satisfactory, and even clay may be used.

[2]If you take the plants for your aquarium from a pond or a stream, remove them very carefully so as not to crush or damage them; otherwise they will die and decay. Put them in a pail together with a little pond water and leave them in it until you plant them in the aquarium.

sand becomes washed away from the bottom of the aquarium and stirred into the water.

Now fill the aquarium with water. This may be done best by means of a siphon, which stirs up the sand as little as possible.[1] If you are making an aquarium at home and have no siphon, use a small dipper or cup and slowly pour the water on the stone in the aquarium. Fill the aquarium about three-quarters full of water. If the water appears muddy the first time that you fill the aquarium, siphon out most of it and add fresh water. When this has been done, if the water still appears cloudy, allow it to stand until it becomes quite clear. A home will then be prepared and ready for the animals that you choose to dwell there.

How to keep an aquarium clean.—Unless an aquarium is cleaned occasionally, its walls will, in time, become green with tiny plants. A stick about eighteen inches long, with a piece of cloth wrapped and tied around one end of it, will be serviceable in wiping off these plants. A few pond snails placed in the aquarium will also help to keep the walls clean because they eat the tiny green plants for food.

To remove the dirt that collects in the bottom of the aquarium use a quarter-inch siphon. The dirt will be drawn into the siphon and can be caught in a pail placed below the level of the aquarium (Fig. 376). As some water will be drawn out of the aquarium along with the dirt, it should be replaced by fresh water.

[1]A piece of rubber tubing about 2½ feet long, with a glass tube about a foot in length inserted in one end, makes an excellent siphon. When filling the aquarium, first put a pail of water beside it. Then hold the two ends of the siphon tube with one hand and fill it with water. (This is easily done if you have a tap.) When this is done, place a thumb or finger firmly over each end of the tube and place one end beneath the surface of the water in the pail and the other end in the aquarium touching the flat stone. Not until then should you remove your thumbs. Allow the water to run from the pail until the aquarium is filled to the required depth. In order to keep the water running it is necessary to have the level of the water in the pail higher than the level of the water in the aquarium. The greater the difference in level, the faster the water will run. The more slowly the water runs, however, the less it will stir up the sand.

If an animal dies in the aquarium, remove it at once. For picking objects out of an aquarium use a pair of forceps made of thin strips of wood from a fruit crate (Fig. 377).

Fig. 376. When water is flowing out through the siphon, it will pick up dirt as the current of air flowing through a vacuum cleaner picks up dust. The straight tube is for capturing small animals. The air is being held in by the finger. When it is released, the water will rush up, taking the tiny animal just below the end of the tube. The finger is then replaced, and the water containing the specimen may be lifted out with the tube.

Stocking an aquarium.—Gold fish for an aquarium may be obtained from dealers, or minnows and other small fish may be procured from a stream. These are easily captured with a net made specially for obtaining specimens from the water (see Appendix, Sec. 2). Add a few pond snails. If you wish to put frogs' eggs or very small water animals in an aquarium, separate them from the fish by a partition (Fig. 378).

How fish move.[1]—Watch your specimen fish carefully as it swims through the water and try to discover how it moves itself about. Does it seem to move its tail fin sideways, first one way and then the other, pushing against the water and forcing itself swiftly along? Does it move only its tail, or does it bend the entire back part of its body? The tail fin is attached to the backbone and is moved by the large muscles along the sides of the body. Not only the tail fin but the whole of the body seems to be bent

Fig. 377. Wooden forceps for removing objects from the aquarium. The block is an inch thick. Round-head screws are best for fastening the side pieces on.

[1]For this lesson each small group in the class should have a minnow or other small fish in a pint sealer or tumbler containing water. (These fish may be kept in a large pail of water until they are required for use in class.) If the class is small, the pupils may all observe the fish in the school aquarium.

and used to push against the water. Do you think that fish with large flat bodies can swim better than those whose bodies are round? The tail not only helps to propel the body along but also serves as a rudder to steer the fish through the water.

How many parts has the body of a fish? Has a fish any neck? Would shoulders on the fish catch against the water and prevent it from gliding swiftly along? People have

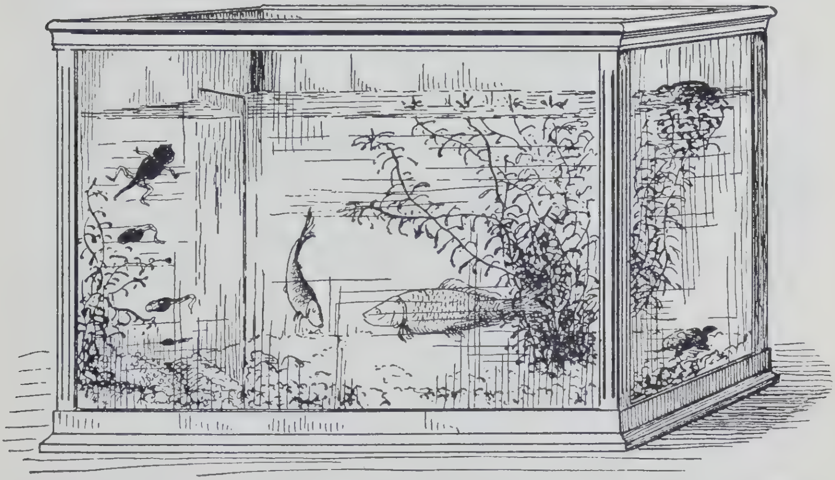


Fig. 378. A good school aquarium stocked with plants and animals. A partition separates the tadpoles from the fish and turtles. Why?

copied the shape of a fish when making submarines because this is the best possible shape for easy movement in the water.

How many pairs of fins do you see? How many fins are there along the middle line of the back? How many fins are there on the middle line on the under side of the body? The front pair of fins correspond to the front legs and the back pair to the hind legs of other animals. Compare your fish with the one shown in Figure 379.

Find out, by watching your fish, what use it makes of its

front fins. Can it move its hind pair of fins? When the fish is moving very slowly, it uses its two pairs of fins. Watch it back up or slowly turn sideways using these paired fins. When the fish is moving swiftly in the water and wishes to stop suddenly, it uses these two pairs of fins as brakes. How? Would very large fins on the sides of the body help the fish to move more swiftly, or would they catch against the water and act as brakes?

The fins on the middle of the back and under side of the body help to keep the fish in an upright position. Do they seem to be spiny and sharp? Do the spines on these fins

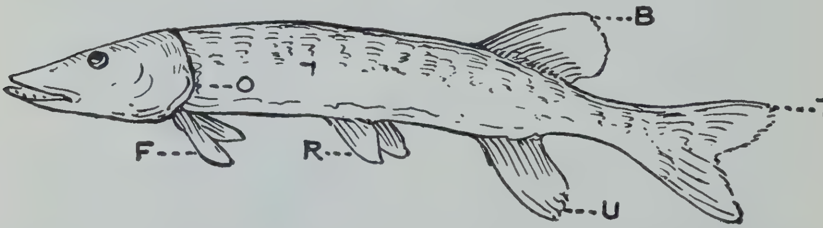


Fig. 379. Jack fish. F, Front pair of fins. R, Back pair of fins. These two pairs of fins take the place of the front and hind legs of many animals. B, Fin along the middle line of the back. Some fish have two fins along the back. U, Fin on the under side of the body. T, Tail fin. What use does the fish make of the tail and the back part of the body? O, Opening where the water which enters the mouth escapes after flowing over the gills. The fish can close this opening by a gill cover.

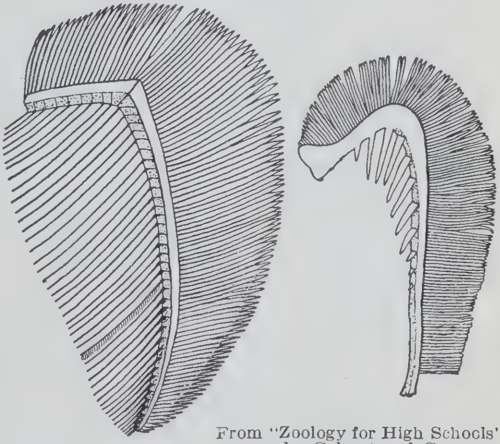
point upward and backward? Would this make it more difficult for a pursuer to swallow the fish?

Have you ever tried to hold a fish in your hand soon after taking it from the water? Is it slippery? Would this slippery surface enable it to move through the water easily? The slimy substance that covers its body enables the fish not only to slide easily through the water but also to slip easily from the grasp of an enemy.[1]

[1]This covering also keeps germs from attacking the body of the fish. If we are not careful, we may become infected when the covering of skin on any part of our bodies is injured. In the same way a fish may become infected when the slippery covering is rubbed from any part of its body. For this reason we should never touch the fish in an aquarium. If we rub off the slimy material, the fish will become sick and die.

How fish breathe.[1]—Watch your fish as it remains at rest in the water. Do you see a long slit-like opening (gill opening) on each side of the head (Fig. 379)? Does it open and close at all? Does the mouth also open and close at about the same time as the gill opening, as though the fish were taking in a mouthful of water and forcing it out through these gill openings on the sides of the head? Notice whether the fish opens and closes its mouth as it swims through the water.

With a small stick, such as a toothpick, or with a pencil open the gill cover of a freshly killed or preserved fish to discover the gills inside. They can be readily seen if you cut the gill cover off one side of the head with a pair of scissors. Look for four gills, each in the form of an arch, as shown in Figure 380. One is somewhat smaller than any of the other three. See whether there are the same number of gills on each side of the head. Notice the appearance of each of the four pairs of gills. Do you see a great number of thread-like "gill filaments" coming out from the bony frame of each gill? This gives the gill a feathery appearance.



From "Zoology for High Schools" by Calvert and Cameron.

Fig. 380. Gills of fish. Is there more surface on the numerous threads or filaments than there would be if they were joined to form a flat membrane? What is the advantage of having a large gill surface touching the water? Notice the spiny "gill rakers." Find them on your specimen. These protect the gills and prevent the escape, through the gill openings, of smaller animals that the fish has captured for food.

[1]For this lesson, besides live fish in water, you also require for each group of about six pupils one freshly caught larger fish or one preserved in 20 per cent formalin in a tall sealer or crock. Smelts or any other small fish obtained in meat shops are quite suitable for preserving.

Close to the surface of each fleshy branch or thread of each gill there are thin-walled blood-vessels. As the water that enters the mouth of a fish passes over the gills, the oxygen of the air dissolved in it passes through the thin walls of these blood-vessels into the blood. At the same time carbon dioxide in the blood soaks out through the thin walls into the water. When the water containing this carbon dioxide flows past the gills and escapes through the gill openings at the sides of the head, it carries away the carbon dioxide.

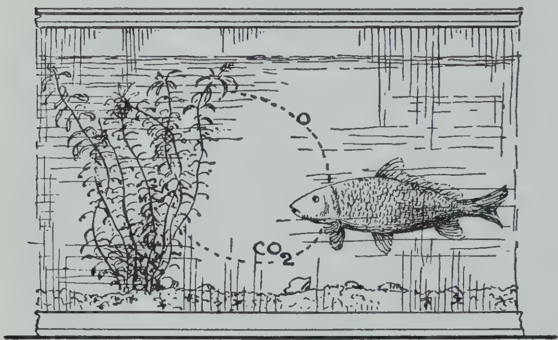


Fig. 381. A balanced aquarium. The green plants give off oxygen that dissolves in the water. As the water goes over the gills of the fish the oxygen is taken from it, and carbon dioxide is given out. This is absorbed by the plant. It keeps the carbon and gives out the oxygen again. If there are no plants, or only a few, the fish must depend for its oxygen upon air dissolved at the surface. Why should the top of an aquarium be large?

Our lungs and the lungs of other animals have in them a great many partitions with thin-walled blood-vessels on their surfaces. When air is breathed into the lungs, it comes in contact with these many surfaces. Some of the oxygen in the air passes through the moist thin walls of the blood-vessels and enters the blood. At the same time carbon dioxide in the blood passes out through these thin walls and escapes from the lungs when the air is exhaled. Fish, therefore, take in oxygen and give out carbon dioxide just as do the higher animals and people when they breathe.

You have learned that green plants change breathed air back to "fresh" air. (See Experiment I, page 421, and Figure 364.) In the daytime plants take in carbon dioxide and use the carbon to make starch and sugar,

giving out the oxygen. Fish and other animals use up the oxygen received from plants and at the same time breathe out carbon dioxide, which, in turn, is taken up by plants (Fig. 381). By this process the water in which fish live is "purified" or supplied with oxygen for them to breathe.

You can now see why we put plants into an aquarium. They use up the carbon dioxide breathed out by the animals and at the same time give out oxygen which is needed by the animals. When you have the proper number of plants and animals in an aquarium, no fresh water containing dissolved air need be added. Such an aquarium is said to be "balanced." What is meant by this expression?

What a fish eats.—What does a fish eat? Examine the stomach of the next fish that you catch. You may find in it crayfish, tadpoles, or other small animals that live in the water; or you may find one or more fish smaller than itself.

One fish usually lays thousands of eggs. Only a few of these ever hatch and grow to be as large as the fish that laid the eggs. Some of the eggs may be eaten before they hatch. Most of the fish that hatch grow until they are caught and eaten by larger fish. Much of the food of large fish consists of their smaller relatives.

How a fish catches its food.—How do fish catch their prey? Have you ever wondered why a fish grabs a large bait with several hooks on it? When a fish sees a bait smaller than itself moving through the water, it darts after it and may take the whole bait into its mouth. Why does the fish not swim up to the bait and look carefully at it before seizing it? As water is more dense than air, light does not pass through it as easily as through air. Therefore, fish, being deprived of much of the light with which we are surrounded, cannot see as well as we can. When one fish passes another, it probably sees no more than the outline of some-

thing moving in the water close at hand. It has no opportunity of examining what is passing, because, if it attempted to do so, the other fish would be frightened and swim rapidly away. A fish therefore always darts after a smaller moving object. If the object happens to be a bait, the fish may be caught.

Has your fish a large mouth? A fish with a large mouth and throat can catch and swallow fish smaller than itself. Its small, sharp teeth only aid the fish in holding and swallowing a struggling prey; they are of no use for chewing food. A fish, therefore, swallows its victims whole. Of what advantage is it to have these sharp teeth turned slightly backward towards the throat? A few varieties of fish, such as suckers and perch, have much smaller mouths than such varieties as pike, whitefish, and pickerel, and must therefore be content to eat only small fish and animals.

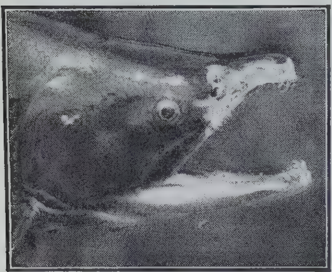


Fig. 382. Head of salmon. What is the advantage to the fish of having a large mouth?

Question Outline

(1) How would you prepare an aquarium in which to keep a fish? (2) Why are plants put in an aquarium (3) How can an aquarium be kept clean? (4) How does a fish move through the water? (5) What use does it make of the two pairs of fins that correspond to the front and hind limbs of animals? (6) Of what use to the fish is the slippery substance on the outside of its body? (7) Where does a fish obtain the air that it breathes? (8) Where does the air enter the blood of a fish and carbon dioxide escape from it? (9) What is the advantage of having gills that are thread-like? (10) When a fish remains quiet in the water, how does it breathe? (11) Why do fish like to swim against the current? (12) On what do fish live? (13) In what way are the mouth and the throat of a fish suited to obtaining its food? (14) How does a fish catch its food?

CHAPTER XLIX

SNAKES

When you were very young, you would doubtless pick up a worm and find great interest in watching it. Many older people, when they find a worm, thoughtlessly kill it, believing that, because it crawls, it should not be allowed to live. Why do people wish to kill creeping things such as worms and snakes? We learn to fear and dislike snakes, not because they have harmed us, but because we have been told that they are hateful creatures and should be killed. So that we may find out *for ourselves* something about these really beautiful little creatures, let us examine one of them.

From Gadow.

Fig. 383. Garter snake. You may identify this common harmless snake by its three yellow, pale green, or red stripes on a dark background. Its head is not triangular like that of poisonous snakes. It is easily tamed.

The garter snake.—As garter snakes are quite harmless, you need not be afraid to handle them. Indeed, they seem to enjoy being handled and soon become tame. The fiery forked tongues that they dart in and out of their mouths will not harm you in any way. These tongues are used, like the antennae of insects, for feeling.

Preparation.—For this lesson bring into the classroom a live snake and put it in a cage. Use the box cage that you prepared for rodents (see Appendix, Sec. 17). Firmly fasten a branch in the box so that the snake may crawl upon it and bask in the sun. The cage may be placed in a sunny window, but there should always be some shade in the box. In the bottom of the box put coarse gravel. Sawdust may be used instead of gravel, but it is not so suitable. On the gravel put some curved pieces of bark in which the snake may hide. It will be afraid of you until it becomes aquainted and learns that you will not hurt it. Your snake may be caught a week or two before the lesson and kept alive with fresh water only. If you wish to keep it longer, feed it small toads and frogs, earthworms, and minnows. Be sure to keep your snake well supplied with fresh water in a small pan about six inches long, three inches wide, and two inches deep. Preserved specimens of snakes should be kept in the school collection in a 20 per cent solution of formalin or in a 75 per cent solution of methyl hydrate. Bring into the classroom also a live earthworm in order to compare the movement of a snake with another crawling animal.

Carefully observe the garter snake that you have caught and put in the cage or found in the school collection. What is the main difference between the shape of the body of the snake and the shape of a rodent's body? Has the snake any legs? By far the greatest number of snakes live in hot countries where there is a dense growth of plants. Could a snake go through this dense growth easily if it had a thick body, and limbs extending out from it? Could it work its way through between the plants easily if its body were stiff?

Place your snake on the smooth surface of a varnished desk or a piece of glass. How does it try to move? Can it move very quickly? Why? Place it on a rough surface to see whether it can crawl more rapidly on this than on the smooth surface. If you have a tub or barrel of water, place the snake in it and watch the movement of its body as it swims.

Since a snake has no limbs to keep its body off the rough ground or rocks, what protects it from injury as it crawls along?

How many light-colored stripes run along the upper side of the snake's body? Of what are they made? What is the color of the scales between the stripes? What is the color underneath the body? Is there any advantage in this arrangement of colors? Do the scales run completely around the lower half of the body? Do they overlap and point backward? Are there scales on the head? Compare the snake with a fish in this respect. Does the body of the snake feel rough or does it feel smooth like satin? Could it easily slide along on the ground or on rocks?

The shape of the snake.—The long, slender form of the snake enables it to crawl through very small openings. The ease with which it can bend in every direction makes it

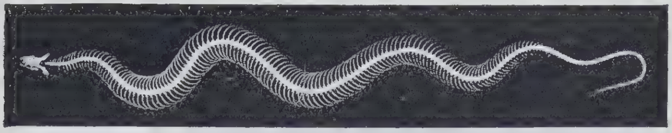


Fig. 384. Skeleton of a snake. The snake has one pair of ribs for each large scale on the under side of the body. How many pairs of ribs has your specimen? What is the advantage of the numerous joints in the backbone?

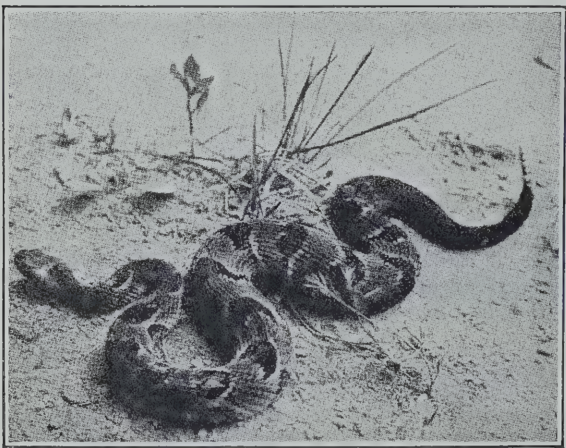
possible for the animal to wind about in dense plant growth as it hunts its food or escapes from its enemies. The smooth scales not only protect it from injury, but also enable it to glide along easily through very narrow passages.

How the snake moves.—You have seen the wave-like motion by which the snake crawls along. By pressing the loops of the body waves against grass, plant stems, and rough places on the ground, the snake is able to push itself forward. The large backward-pointing scales on the under side of its body help it to grip firmly the surface over which it is moving. Allow the snake to crawl over your hand so that you may feel how the scales take hold.

Place an earthworm in a wet plate or dish and observe it crawl. Does it move its body from side to side in a wave-

like motion as the snake does? Does it seem to move forward by first lengthening the front part of its body and then shortening its body by pulling the back part forward? Unlike the worm, the snake has a long backbone, which prevents it from lengthening and shortening its body in order to move but enables it to bend strongly sideways (Fig. 385).

Kinds of snakes.—Snakes may be divided into two groups: those that are venomous (*venenum*, poison) and those that are non-poisonous. Because poisonous snakes sometimes kill human beings, they have caused people to hate all snakes, whether poisonous or not. Is this fair to the non-poisonous snakes? When we learn the difference between these two groups of snakes, we may protect those that are beneficial to us.



Courtesy New York Zoological Society.

Fig. 385. Rattlesnake. Notice the rattle on its tail that gives warning to enemies. Like other poisonous snakes, this one has a triangular head and a pit or hollow between the eye and the nostril. The pupils of the eyes are slit-shaped like those of a cat, not round like those of non-poinsonous snakes. This dangerous snake is useful as an enemy of rodents.

Snakes, like toads and frogs, are cold-blooded animals (see page 436) with a body temperature about the same as the temperature of their surroundings. As they cannot keep themselves warm, they naturally like to live where it is warm all the year around.[1] The number of snakes found in Canada, therefore, is small in comparison with the numbers found in countries farther south.

[1]This explains why snakes, when tame, like to be held in your warm hands.

We have one kind of snake living in Canada that is poisonous. We have all heard of the rattlesnake, but few of us will probably ever see one in its native haunts (Fig. 385). On its tail is a rattle made up of little sections. About three new sections are added each year. On the upper jaw of the mouth is a pair of hollow teeth called *fangs* (Fig. 386). When the snake *strikes*, it throws the front part of its body forward for a distance of not more than two-thirds its length, and with its fangs makes a wound. At the same time it forces poison from two sacs in its head down through its hollow fangs into the wound. As this poison is very deadly, treatment should be given at once.[1]

From "Zoology for High Schools" by Calvert and Cameron.

Fig. 386. Head of rattlesnake showing the two large fangs in the upper jaw. Notice the large size of the mouth. Snakes can swallow prey larger in diameter than their own bodies.

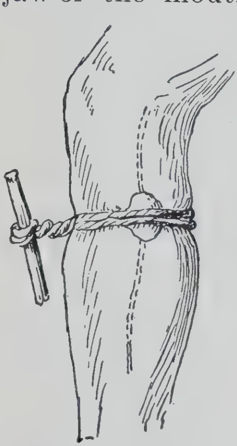


Fig. 387. Tourniquet placed below the knee. A small stone or a hard knot made in a handkerchief and placed under the tourniquet on the inside of the leg will aid in stopping the flow of blood. Snake bites are usually on the legs or arms. By immediately stopping the flow of blood with two or three tourniquets placed between the wound and the body, we may prevent the poison from being carried by the blood to the heart and brain. The wound should bleed freely to drain out the poison.

[1]*Treatment for snake bite.*—(1) Tie a handkerchief, a strong cord, a piece of tape, or a strip of cloth around the injured limb near the trunk of the body and tighten it by placing a stick or other small object under the band and twisting it (Fig. 387). Then put one or two similar bands between this band and the wound. (Practise this on your own arm.) This will prevent the blood containing the poison from flowing back to the heart and poisoning the whole body. The band should be put on *immediately* after the wound is made but MUST NOT be left on longer than twenty minutes. (2) With a sharp knife cut the wound open so that it will bleed freely and thus drain out the poison. Bathing the wound with warm water and keeping the limb as low as possible will also encourage bleeding. (3) Now rub well into the wound some powdered potassium permanganate, or thoroughly wash it with a strong solution of it. (If you have no potassium permanganate, use iodine.) (4) Call a doctor at once. (5) When bleeding ceases, cover the wound with clean gauze, place over this a bandage, and remove the tight bands. As there

Rattlesnakes are rare in Canada and other poisonous snakes very rare indeed. Nearly all of our snakes are not only harmless but beneficial.

Value of snakes.—Various kinds of animals serve us in various ways. Grazing animals, as we have seen, supply us with food and clothing, and help us to do our work. Many carnivorous animals supply us with furs and help to destroy rodents. Most birds are of great service to us by destroying large numbers of insects and harmful rodents. To discover how snakes are of use to us we must know what they eat.

Fig. 388. Black snake crawling up a tree. Notice the "waves" in the body.

Garter snakes and *water snakes* live entirely on cold-blooded animals. Unfortunately they eat toads, frogs, fish, and earthworms, which are useful to us, and occasionally they also take birds' eggs from nests on the ground. Their young, however, are of some value because they destroy insects and insect larvae.

The little *brown snake*, which grows from eight to fourteen inches long, is a very beneficial snake because it lives on insects, insect larvae, and other very small harmful animals. It is very gentle and will not bite.

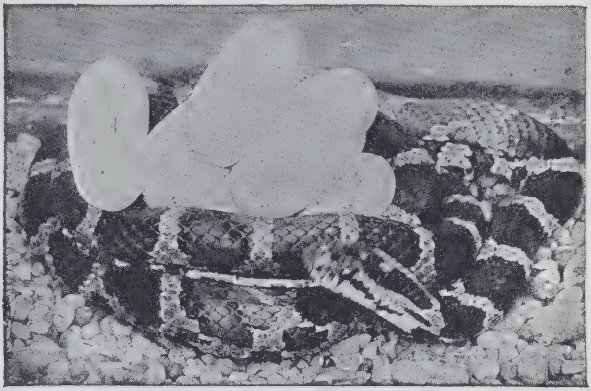
You may have seen little *green snakes*, or grass snakes as they are sometimes called. It is difficult to see them because they are green like the grass about them. They are very gentle and harmless and should be protected because they live almost entirely upon insects.

Black snakes, which grow in this country to a length of several feet, are non-poisonous. Unlike garter snakes, black snakes catch and eat warm-blooded animals. Many

is great danger of blood-poisoning following a poisonous snake bite, the wound should be kept thoroughly washed with disinfectant and covered with clean gauze. People going on motor trips to the south should carry a sharp knife, a little powdered potassium permanganate, gauze, and iodine. Leggings are a good protection against poisonous snakes.

farmers have discovered that snakes of this variety rid their barns of rats and mice and destroy other rodents about the farm. They may take an occasional bird or a small chicken, but the harm that they do is very small compared with their usefulness.

One of the prettiest snakes that live in our country is the *milk snake*, wrongly named because it was falsely accused of milking cows (Fig. 389). It may be found about barns and fields, hunting for mice and rats. It is correctly named *king snake*, because it is able to kill other snakes, poisonous as well as non-poisonous. This snake is quite harmless and, because of its usefulness, deserves our protection.



From Ditmar's "Reptile Book" by courtesy Doubleday, Page & Co.

Fig. 389. Milk snake. This beautiful "king" snake is guarding her eggs, which are hatched by the heat of the sun. Why should this snake be protected?

Question Outline

(1) What shape is a snake's body? (2) In what important way does a snake differ from other animals that you have studied? (3) Of what use are the scales on a snake? (4) What enables a snake to make its way through a dense growth of plants? (5) How does it move? (6) Do its scales help it to move? (7) What two groups of snakes are there? (8) How can you tell whether a snake is poisonous? (9) Where is the rattler on a rattlesnake? (10) How would you treat a snake bite? (11) In what way are garter snakes ~~beneficial~~? (12) In what way are they harmful? (13) Give good reasons why most of our snakes should be protected. (14) Many useful animals are destroyed by thoughtless people. What should we do before destroying any animal?

Conclusion.—We set out to make a study of our plant and animal neighbors and of the water and the air about us. Indoors and out we have watched them and tried to find answers to the many questions that they have brought to our minds. We have found that we can discover these answers only by first seeing our specimens and our experiments with our own eyes. This is **observation.** We have been able to discover the right answers to our questions only where we were careful to see correctly. This is **accuracy.** When we have seen correctly, we have been able to think out the meaning of what we have seen. This is **reasoning.** By observing accurately and reasoning carefully, often with great difficulty, we have gained some **skill** in answering more and more difficult questions.

We have made, let us hope, good progress after making a good beginning, and, though there are countless questions yet to be answered, we have discovered many useful and interesting facts. These facts, together with many other things that we have yet to learn, make up part of the great store of human knowledge that people have built up by patient observation and experimenting followed by careful reasoning.

By means of the specimens and the experiments that we have studied we have been able to obtain at least a glimpse of the things in the world around us. It is as though we could look out from our science room table through an archway of which the keystone is **Truth.**

APPENDIX

1. Two experiments to be commenced in the third week in September.—The sun is our great source of heat. As our winter weather is colder than that of summer, we are led to inquire why we do not receive the same amount of heat at all seasons of the year. Three questions naturally present themselves for solution: (1) Does the sun rise to the same height in the sky each day of the year? (2) Do the positions of sunrise and sunset shift throughout the year? (3) Do the hours between sunrise and sunset vary from time to time? We can answer these questions for ourselves by performing the following two experiments.

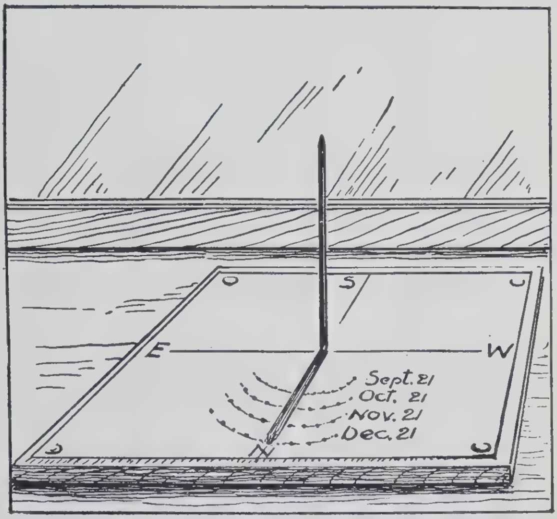


Fig. 1.

Experiment I

Object.—To discover whether the sun rises to the same height in the sky at noon each day throughout the year.

Apparatus.—A 3-inch nail, a board about 6 inches square, a sheet of white paper.

Method.—Drive the 3-inch nail through the centre of the board. Tack over the board a piece of paper (Fig. 1). Place the board on a window sill or in some other convenient position that faces south. See that the board is level.

During the time between 11.30 and 12.30 as shown by the clock, put a small mark on the paper each five minutes, indicating the positions of the tip of the nail's shadow. Join the marks thus made with a line to show the path of the tip of the shadow. Now mark the exact position of the

board on the window-sill so that it can be placed there again later on in the year. Put the apparatus away carefully for future use. Make a careful record in your note-book showing the date and what was done.

Repeat this process on the 21st of each succeeding month throughout the school year. Keep in your note-book a diagram of the different paths of the shadow together with the dates on which observations were made.

Observations.—(1) Does the sun rise higher in the sky at one time of the year than at another? (2) About what date did you find the tip of the shadow closest to the nail at noon? Would the sun be high or low in the sky at that time? (3) On what date did it lie farthest from the nail at noon? Would the sun be high or low in the sky at that time? (4) On what two dates in different months was the shadow of the nail about the same length? What does this observation show?

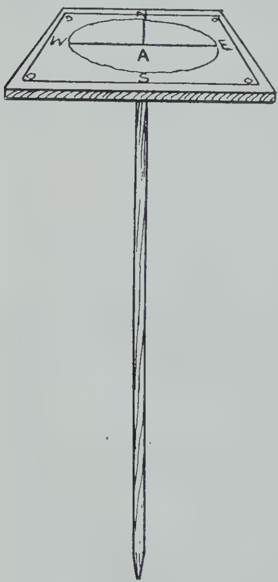


Fig. II. Stand to hold cardboard.

Conclusion.—Why do we not receive the same amount of heat at all seasons of the year? To help you in answering this question see Figure 145, page 182.

Note.—At the moment in each day when the tip of the shadow comes closest to the nail the sun will be due south of the nail, and the time will be noon *by the sun.* Compare it with the time as shown by the clock. If there is a difference, find out why.

Project.—Find out how a sun dial is constructed and make one for finding out the time from the sun.

Experiment II

Objects.—(1) To find out whether the positions of sunset and sunrise vary from time to time. (2) To find the hour of sunrise and sunset at different times of the year.

Apparatus.—A piece of cardboard about 10 inches square, a compass, a stand.

Method.—Choose some location near your home from which you can observe the position of both sunrise and sunset. Indicate this position on your cardboard by the point A, and draw a circle almost as large as the cardboard about this point. Place the cardboard on a stool, box, or stand made for the purpose (Fig. II) in such a positon that the line EW

drawn across the centre of the circle points east and west, while the line AN, drawn at right angles to it, points north and south as shown by the compass or other means of finding north.

Stick a pin in the board vertically at A (Fig. III). Place one eye in line with this pin and the setting sun. Place another pin on the circle in line with A and the sun. Call this point B. Join AB with a line. Notice some prominent object on the landscape along the line of vision between A and the setting sun. Label it C. At the bottom of the cardboard record what C represents. Above the point B, as shown in the diagram, write the date and the exact time at which the sun set.

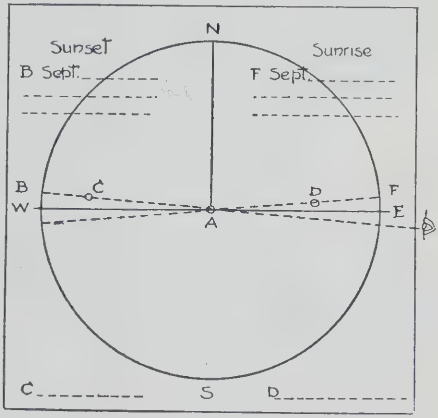


Fig. III.

The next morning, or on the next morning that the sun can be seen rising, go to your chosen location and place your cardboard in exactly the same position with AN pointing north. Now place one eye in line with the pin at A and the sun. Place another pin on the circle exactly in line with the pin at A and the rising sun. Call this point F. Join AF with a line. On this line indicate with a letter any prominent object lying along your line of vision, and state at the bottom of the card what the letter represents. Record the date and the exact time of sunrise above the letter F.

Using the same apparatus, repeat this process on or near the 21st of each succeeding month. Since sunrise is quite early in April, May, and June, it may be advisable to discontinue observations in the morning during these months.

Alternative Method.—If you have no means of finding exact north, you may use the following method to discover whether the position of sunset changes. From a piece of wood about the size of a lath or a yard ruler make three pieces, one about 14 inches, another 12 inches, and a third about 10 inches long. Drive a 2-inch nail as far as it will go through one end of each piece, placing it about ½ inch from the end and on the middle line of the strip of wood. Do the same at the other end of each strip, taking care to drive the nails through from the same side each time. Now find the centre of each piece and make a hole through it with a gimlet or a 2-inch nail.

Locate a fence post or other flat-topped solid support from which you can observe the position of sunset. A little before sunset go to the post, taking with you the three strips of wood, a 3-inch nail, and two or three shorter nails. Place the three strips in a pile with the longest on the bottom and the shortest on the top, keeping the nails upright in each case. Push the 3-inch nail down through the centre holes of the three strips and nail the strips to the top of the post.

Turn the bottom strip until it is pointing towards the setting sun. The two upright nails will help you to find the exact direction. Nail the strip solidly to the post with two or three more nails to hold it firmly in that direction. In your note-book write down what you have done and record the exact time of sunset. The next morning observe and record

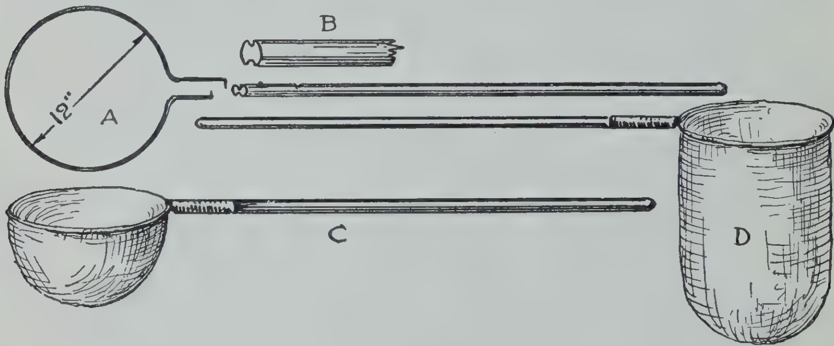


Fig. IV.

the time at which the sun rises. (If you wish, you may make three more pieces of wood similar to those already described and use them for finding whether the position of sunrise varies.)

On December 21st, at sunset, direct the second strip of wood so that it points towards the setting sun. Nail it firmly in this position as you did the first one. Record the hour of sunset on that date and again the following morning.

On March 21st, at sunset, observe whether the bottom strip of wood points towards the setting sun. Record the hours of sunset and sunrise and compare them with your record for September 21st.

On June 21st, at sunset, turn the top strip of wood in line with the setting sun and nail it in this position. Again record the exact hour of sunset and sunrise. (If on any of the dates mentioned above you cannot see the sun because of clouds, make your observations as soon afterwards as possible.) For a week after you have nailed your last strip in position notice whether you can observe any change in the direction of sunset.

Observations.—In your note-book keep a copy of the diagram and other information placed on your cardboard. If you have used the *Alternative Method*, make a diagram showing the directions of the strips of wood on the dates given and label on it the date and hour for each direction.

Conclusions.—(1) What are the changes in the direction of sunset and sunrise throughout the year? (2) Does the length of day vary throughout the year? How many hours of sunshine do we have (*a*) on September 21st? (*b*) on December 21st? (*c*) on March 21st? (*d*) on June 21st? (3) Give two good reasons why summer is warmer than winter.

2. Insect nets.—Nets for collecting insects may be made as follows: Bend a piece of heavy wire as shown at A (Fig. IV), making the loop about 1 foot in diameter. Fit this to a handle by placing the two long, straight pieces of wire along two grooves, one cut in each side of the handle (see B),

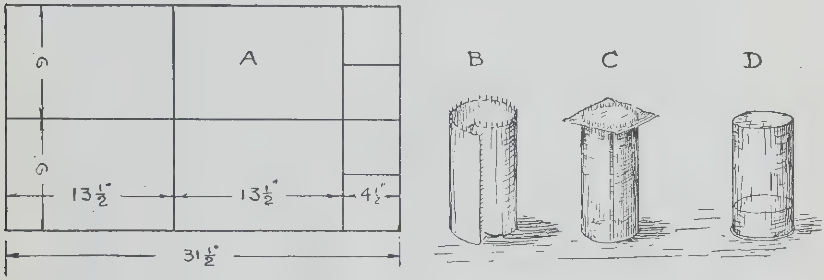


Fig. v.

and driving the ends of the wire into the wood. Bore holes if necessary. Bind the wire to the handle by wrapping it tightly with fine wire.

For catching insects in water, sew a net made of fairly open material, such as Brussels net, to the wire loop, making the net no deeper than the radius of the loop (see C).

For catching insects in the air, use cloth mosquito netting or Brussels net. Make the net a simple bag-shape, with its depth at least twice the diameter of the loop.

3. How to make an insect cage.—Using the sharp edge of a tin can that has been cut off below its thick rim, cut a piece of turf to a depth of about 2 inches, and remove it from the ground. Fill in the lower part of the can with soil or sand and plant upon this the circular piece of turf, pushing it down about ½ inch below the rim. Water the grass so that it will keep fresh.

Next, make a cylinder of wire screen that will fit closely around the can, following the suggestions in the diagrams (Fig. v). Buy screen 18 inches wide, and cut it along the middle, making two 9-inch strips as

shown at A. This leaves a selvedge along one edge of each strip, which is advisable.

Roll a 9-inch strip of the netting around the can to see what length is required for the sides of the cage. Cut off a length that will overlap about 1 inch at the seam, as in B. Pull out two wires along each vertical edge. Bend the projecting wires outward at one end of the strip and inward at the other end as in B. Push these ends through the screen and clinch them, making sure that the cylinder thus formed fits snugly on the can. Slip the cylinder on the can with the selvedge at the bottom.

Now pull out two wires around the top. This leaves the ends of the vertical wires protruding about ¼ inch. Press down upon these a piece of netting four and a half inches square, as shown at C. The vertical wires

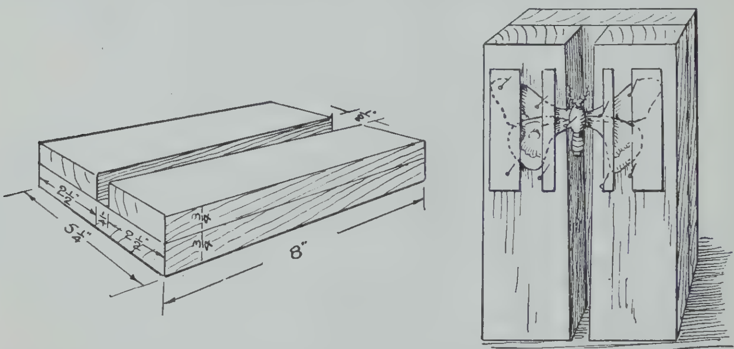


Fig. VI. Spreading boards are described in many of the insect reference books, but the above will give a good idea of their construction and use. On the right is shown a surface view of a spreading board with an insect. (The rear edge of the front wings should be placed at right angles to the body.)

will project through it. Bend them outward until they lie flat. Trim off the corners of the square, cutting about ¼ inch outside the circle all round. Then bend the projecting rim downward tightly against the sides of the cylinder, and the cage will be complete as shown at D. The wires that were pulled out may be used to sew the edges together for extra strength both around the top and along the vertical seam. If a cage less than 9 inches high is preferred, cut the strip of screen narrower.

4. Spreading board for insects.—Long boards accommodate more insects, but short ones (6 to 8 inches) are more convenient (Fig. VI). Make the groove wider at one end than at the other to suit insects of various sizes. The depth of the groove should be about ¾ inch. Unless the wood in the base of the board is very soft, put a strip of cork or linoleum in the bottom of the groove.

Proper *insect pins* should be used for piercing the body of the insect and attaching it to the bottom of the groove. Steel pins with large black heads are best for pinning down the strips of paper over the wings.

5. Moth-proof case for insects.—Insects that have been dried on a spreading board may be mounted in moth-proof cases similar to that shown in Figure VII. Chalk boxes sliced with a saw as indicated (Fig. VIII) make excellent frames. Use two pins through the insect's body to prevent it from turning. In this mount specimens will survive a great deal of handling.

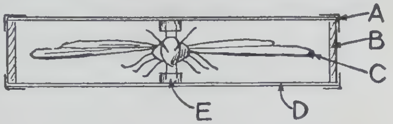


Fig. VII. A, Tape. B, Wooden frame. C, Insect mounted on two pins. D, Glass. E, Cork attached to glass with glue.

6. Permanent picture mounts.—Pictures to be handled by pupils are quickly ruined unless kept under glass. Place the picture face upward on a piece of cardboard. Cover it with a piece of cleaned glass of the same size and bind the parts together around the edge with craft paper gummed parcel tape ¾ inch wide and moistened with a 10 per cent solution of gylcerine in water. If desired, two pictures may be turned back to back and taped between two pieces of glass of the same size. A convenient size for magazine pictures is 6½ by 8½ inches. Half this size is also convenient for pictures and for chalk-box mounts (Figs. VII and VIII).

7. How to preserve and mount a bird's wing in a moth-proof case.—After putting some salt on the fleshy part near the base of the wing, spread the wing out on a piece of board and pin or tack it there. Leave it in this position until it dries and becomes stiff. Make a wooden frame large enough to contain the wing and about 1 inch deep. A stout pin in each corner will be sufficient to hold the frame together until it is taped (see A, Fig. IX). Cut two pieces of glass the same size as the outside of the frame. Attach one of these pieces to the frame with craft paper gummed parcel tape ¾ inch wide, moistened with a 10 per cent solution of glycerine in water. Glue three small corks by their broad ends to the inside of this glass in suitable positions to support the wing as indicated in the diagram. (See B.) Allow the glue to dry. Lay the wing on these three corks and insert three short pins. Place three more corks directly above the first three, and try on the other glass to be used as a cover. Cut the corks, if necessary, to make them fit firmly between the glass and the wing. (Razor blades are good for cutting cork.) Mark on

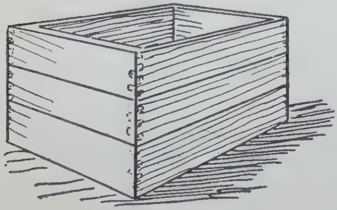


Fig. VIII.

the outside of the glass where the corks are to be. Then glue them in place. Allow the glue to dry, then replace the glass, and tape it to the frame. A double thickness of tape will make the box stronger.

8. Seeds and germination (see Chapter XXIII, page 203).—(1) Soaked seeds are required for study of external structure and internal structure as indicated under specimens on page xix. These may be used freshly soaked for 24 hours, or may be kept in sealers in 5 per cent formalin ready for use at any time. When they are required, the formalin may be poured off and the seeds rinsed several times with water before they are distributed. Fresh formalin once a year will keep the stock supply in better condition.

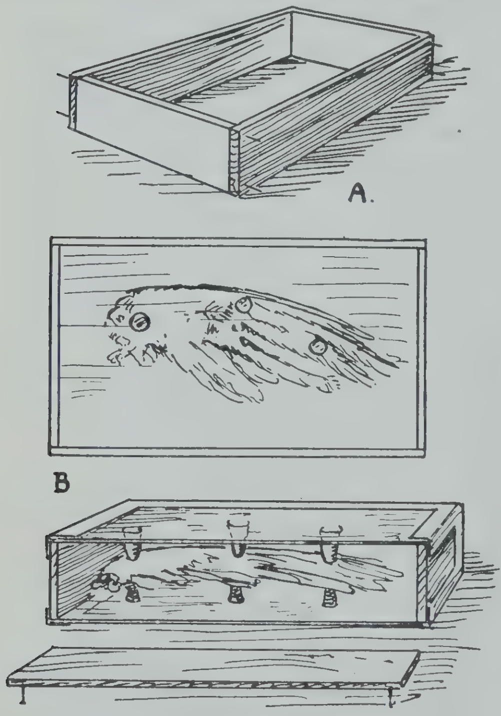


Fig. IX.

(2) Sprouted seeds may best be provided as preserved specimens. These will be examined after pupils have planted their seeds in tumblers and while waiting for them to grow. They may best be prepared as explained under *Germinators* (see below, also Fig. x). To be ready when required, the seeds must be placed in the germinator a week or more in advance of the need, i.e., about the time the study of germination is begun. They may be stopped at the required stage (first root branches showing) by dropping them into 5 per cent formalin.

(3) *Pupils' individual experiments in germination of seeds.*—As directed in Chapter XXIII, the seeds that are to be observed to the completion of germination should be planted in clear glass tumblers.

Soil and sand are less suitable materials for classroom use in this experiment than bulb-fibre-compost, peat-moss, or sawdust. These substances are much cleaner for pupils to handle, less likely to break the tumblers, and more easily cleaned up from desks and floor. Nurserymen use

the fibre for bulbs and the moss for packing plants. The bulb-fibre-compost is cocoanut fibre mixed with charcoal and limestone. These ingredients tend to check decay and prevent souring. Five pounds will fill 20 tumblers. Spnagnum or peat-moss, preferably chopped fine, is excellent material and is obtainable in swamps in many districts as well as from dealers. Living moss should be dried out before using. Sawdust, if fresh and clean, is fairly satisfactory but holds less air and is more inclined to become sour if too much water is given. A tumbler lined with blotting paper, preferably dark gray or blue in color, and filled with sawdust, is a satisfactory alternative arrangement. Outdoor garden planting is a useful supplement to this work, but should not entirely replace it.

The following procedure saves time in large classes:

First Lesson: (1) Have each pupil spread a piece of wrapping paper on the top of the desk. (2) Give out a tumbler and some fibre to each. (3) Put the coarser bits of fibre in the bottom to allow drainage, fill to within ¾ inch from the top with finer fibre, packing in firmly but not too tightly. Collect the spare fibre from the desks. (4) Mark out tumbler covers on wrapping paper with cardboard or wooden patterns previously made. The pattern is easily made by rolling a tumbler in paper (three layers) and trimming off the ends with scissors. The cover should be long enough to go at least three times around the tumbler, and half an inch wider than the height of the tumbler. Cut out the cover, wrap it around the tumbler, and fasten the ends with brown craft paper tape the same length as the tumbler. Remove the cover carefully and fasten the inner end with tape. Print the name, etc., on the cover and replace it.[1] Write an account of the preparation and draw a diagram of it if time permits. Fill the tumblers to the top with water and leave them to soak until the next lesson.

Note.—The seeds that are to be planted during the next lesson should be placed in water 24 hours before required. Two of each per pupil.

Second Lesson: (1) Give each pupil two soaked seeds each of pea, bean, corn, sunflower, and one smaller kind, e.g., buckwheat, radish, or wheat. (2) Remove the paper cover and about half of the moist fibre from the tumbler. (3) Lay in two beans, one pea, one grain of corn, and one sunflower seed, selecting the best seeds from those provided. Place the sprouting side against the glass and space them evenly, leaving one vacant space for smaller seeds. Place some upright and others in other positions. One of the beans may be planted in the middle of the tumbler

[1]If the tumblers are not all alike, covers may be made by rolling each tumbler in three layers of paper. Trim off the top and the bottom of the roll, leaving the ends extended a quarter of an inch above and below the tumbler.

if the seeds are crowded. (4) Carefully replace the fibre taken out, leaving no air spaces around the seeds. (5) After the fibre has been replaced, make two small holes close to the glass where you left the vacant space and drop in the two small seeds. The depth should be equal to five times the diameter of the seeds. (6) Add ½ inch of water, warm, or at room temperature. (7) Print on the paper cover the date of planting and the names of the seeds planted. Replace the cover and set away the tumblers in a place where the temperature will be between 70° and 75°F. if possible.

9. Rag doll germinator.—For germinating and also testing seeds for a whole class or a number of classes, the following method may be satisfactorily employed: (1) Cut strips of fairly heavy factory cotton or similar material (cheesecloth will not do) 10 inches wide and 2 yards long. Make one strip for each 300 large seeds, such as peas, or 600 small seeds that you wish to germinate. (2) Using a common soft lead pencil, divide the

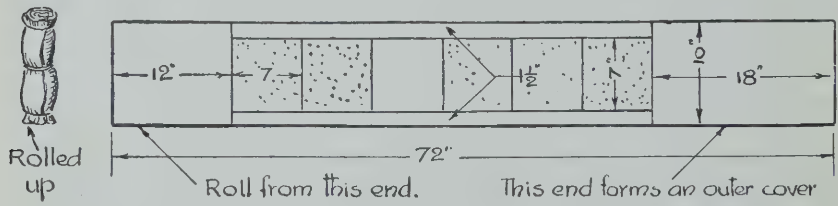


Fig. x.

cloth as shown in Figure x. (3) Soak the cloth in water, preferably warm, and spread it out. (4) Place the seeds to be germinated or tested on the six small squares. See that they do not touch one another. On each square put 100 small seeds, such as wheat, or 50 large seeds, such as beans or peas. By arranging them so that their sprouts will grow towards the same side of the cloth, and by marking and keeping this side downward during germination, much better specimens with minimum breakage will be secured. (5) Roll up the strip, beginning at the shorter vacant end. Then loosely tie each end and the middle of the roll with strings or elastic. (6) Soak this simple rag doll germinator with its seeds in a pail of lukewarm water over night. (Several may be soaked at the same time if required.) Cover the pail well and wrap many layers of newspaper around it to keep it sufficiently warm. (7) Drain off the water. Lay a wet cloth over the germinators. Cover the pail with paper to retain the heat and keep it in a warm place for two days. Remember to keep the germinators on end. (8) Soak the roll in water again for about ten minutes, drain off the water, and store as before from two to four days according to the temperature of the room.

NOTE.—The rolls may be opened at intervals and seeds taken out that have reached any desired stage of germination. These may be preserved in sealers in 5 per cent formalin to show various stages in germination.

10. How to cut a piece of glass tubing.—Support the tube firmly under the point at which you wish to cut it. Draw one edge of a three-cornered file firmly across the point on the glass tube where you wish to make the cut. This will notch the glass. Then clasp your hands around the tube at each side of this notch, which should be turned away from you. Place the tips of your two thumbs at the point on the side of the tube opposite to the notch and press them firmly against the glass, bending it outward at that point.

11. How to bend glass.—With your hands grasp the piece of glass tubing at least a short distance on each side of the place where you wish to make the bend. Then rotate in a flame the part of the tube to be bent, at the same time moving it left and right for a distance of an inch or so to obtain even heating and avoid flattening the tube when it bends. When the glass becomes soft, release one end and hold the other so that the glass may bend by its own weight in the direction required.

12. How to round the sharp edges of a piece of glass tubing.—Hold the end in a flame until the edges commence to melt. Then remove it.

13. How to keep rubber stoppers.—To prevent stoppers from becoming hard, put them in a sealer containing water that has been recently boiled and cooled, and close it tightly. If water freezes in your school, remove it from the sealer during the winter months. If a stopper becomes hard, file off the hard surface.

14. How to insert a glass tube or thermometer in a rubber stopper.—Wet the tube or thermometer with water. If it fits very tightly into the stopper, use a little soap or vaseline, but be careful to keep these from touching the outside of the stopper. Wipe carefully after inserting.

15. Dust-proof cases made from celluloid.—Such specimens as mounted birds or animals, or whole plants of wheat and other grains soon perish if they are not kept in dust-proof cases. Glass cases are expensive and fragile, but good substitutes may be made from sheet celluloid such as is used in automobile curtains. Ask for Dupont sheet celluloid (transparent pyralin) in sheets 20 inches $\times$ 50 inches and $\frac{15}{1000}$ inches thick. Cellulose acetate is similar material, less inflammable but more expensive.[1] As cement for making joints use collodion (U.S.P.) or Dupont household cement.

[1]Both may be purchased from Arlington Co. of Canada, Winnipeg. Price to schools about 70 cents per sheet. Seamless tubes up to 5 inches in diameter may also be obtained.

An oval moth-proof and dust-proof case for a mounted bird may be made as follows: (1) Cut oval openings in two sheets of cardboard of suitable size for the top and bottom. (2) Using these as a pattern, cut two ovals of celluloid ¼ inch larger all round. (3) Cut a sheet for the vertical sides, length ½ inch greater than the perimeter of the oval openings, width equal to the height of the case. (4) Make this into a cylinder, lapping the ends ½ inch, cementing them together and pressing them firmly until dry. (5) Slip a cardboard oval over each end of this cylinder, placing each 2 inches from the end. (6) Stand the cylinder on end on one of the celluloid ovals with a ¼-inch margin showing all round. Hold it in place with a weight. (7) Fasten it with cement, applying several coats. (8) When dry, trim off the margin. (9) Place the base of the bird mount suitably on the other oval of celluloid and fasten it with tacks or cement.[1] (10) Cover the bird with the case already made. Apply cement to the edge of the case and trim as before, when dry.

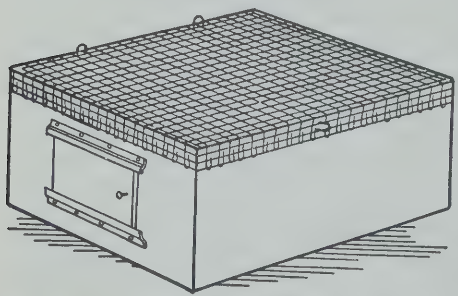


Fig. xi. A simple box cage with sand screen cover and a door in one end.

A suitable case for a wheat-plant is a long narrow cylinder with caps cemented on the ends. Practise with small pieces of material before attempting to make a large case.

16. Keeping animals. — In order to keep animals healthy, cages must be airy and light. A wooden box with wire screen top is therefore not suitable for a permanent cage except where there is plenty of sunlight. Two such cages may be used alternately for some time for animals that will not gnaw their way out through the wood. One cage can be cleaned and food placed in it while the animals are in the other cage. If two cages are required for use at the same time, a third should be provided for making the changes. Keep the animals only as long as you can keep them in clean, comfortable quarters and well fed. They will not suffer from hunger over a week-end if left with plenty of food and water on Friday night and fed again on Monday morning. For proper food see *The Pet Book* mentioned in the footnote on page 292.

17. Making a box cage.—A suitable screen top may be made from

[1] If it is possible that there are moths in your specimen, attach to or conceal in the wooden mount a little bottle, loosely stoppered with cotton batting, containing a teaspoonful of "dichloricide" (paradichlorobenzine) as used in museums for destroying moths. The fumes will destroy any moths that hatch out.

¼-inch mesh sand screen obtainable in hardware stores. The only tools required are a pair of tinsmith's shears, or other means of cutting the screen, a pair of pliers, and a hammer. This screen is sufficiently stiff so that, when its edges are turned down and the corners fastened by hooking the wires together with pliers, it forms a strong lid that needs only two staples for hinges and one for a fastener (see Fig. xi). To prevent fraying, the ends of the wires should be bent over where they are cut. A box cage should have two square feet of screen surface for each animal as large as a squirrel.

As it is inconvenient to clean out such a cage with the animals in it, it is wise to remove them before cleaning and arranging food. A sliding door may easily be made on one side of the cage through which the animals may escape into another cage similarly provided with a door. The second cage should be similar to the first, and, if it is made ready for the animals before they are admitted, they may be left in it until it is time for the next change to be made.

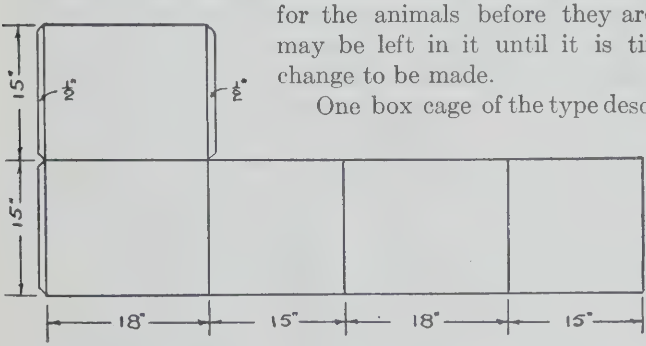


Fig. xii.

One box cage of the type described and one all-screen cage make a very useful combination In a box about 18 inches long × 12 inches wide × 10 inches high, and a screen cage 18 inches long × 15 inches wide × 15 inches high, animals may be kept very comfortably.

18. Making a screen cage.—A metal cage of the proper size makes a healthful home for any animal and one from which it cannot gnaw its way out. An all-metal screen cage is easily constructed. A simple one may be made as follows:

Make a shallow rectangular pan by cutting out the corners and turning up the edges of a sheet of zinc or galvanized iron, or better, have a tinsmith make the pan with proper joints and put a wire in the edges to stiffen them. The bottom should be about 15½ inches × 18½ inches and the depth about 2 inches. Then cut a piece of sand screen of ¼-inch mesh as shown in Figure xii, and bend it over to form the cage as in Figure xiii. Notice that the selvage forms the bottom. Before making each bend, measure carefully so that the cage, when completed, will fit inside the shallow pan. The corners may be kept straight and square by

bending over the edge of a board. To make a strong joint, the ends of the wires sticking out along the cut edges have only to be bent over and hooked together with pliers. The ½-inch strips along three edges are extra material to be frayed out, leaving the ends a little longer for fastening together. Sharp ends of wires should be left on the outside to avoid injury to the occupants of the cage.

The cage may be fastened into the tray by means of a piece of stiff wire pushed through the screen and through two holes in the sides of the pan as in Figure XIV. After the wire is inserted, it is held in by turning downward the end (*Z*), inside the pan as shown. One of these wires is placed near each end of the cage.

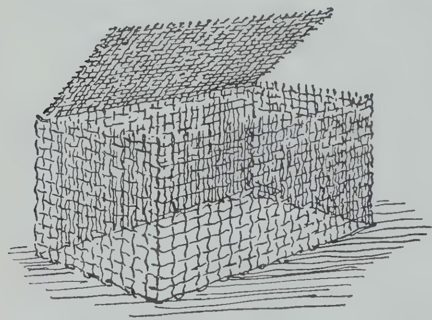


Fig. XIII.

The cage is now complete and ready for use in its simplest form. It is more convenient if a doorway is cut in the top or in one side. The doorway should be large enough to permit reaching in to bring out the water pan for cleaning. Some of the spare screen may be used to make a door. For white rats or other small animals a chalk box attached to the wall in one corner, as at Y (Fig. XIV), makes a clean comfortable nest. A small drinking pan kept filled from a bottle attached to the outside of the wall is also a help in keeping the water clean and the floor dry. Suggestions are given in Figure XV. The drinking pan should be firmly held in place but easily removable for cleaning. A fairly heavy base made of cement or plaster of Paris prevents it from being upset.

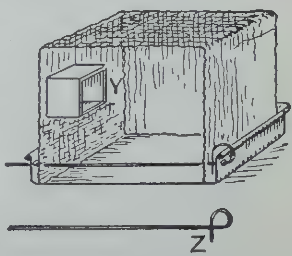


Fig. XIV.

When the cage is complete, cover the floor with dry sand, soil, sawdust, or newspaper, and keep it clean.

19. Storing the school collection.—Useful specimens have value not only on account of their usefulness but also on account of the amount of work, time, or money that they have cost and that would be required to replace them. It is economy, therefore, to invest part of each year's allowance in cupboards and other storage space for the school collection. Perhaps the most useful space when beginning the collection is a strong shelf along the top of the blackboards. It may be supported by the ordinary type of metal shelf

brackets placed above it instead of below. It should be eight to ten inches wide with a ¼-inch edging to prevent objects from slipping off. Specimens carefully mounted, in sealers or otherwise, and placed on this shelf are a strong incentive to further collecting, particularly if the labels attached to the mounts show the names of pupils or ex-pupils who obtained or mounted them. Some closed cupboard space should be secured as well, preferably of mouse-proof construction. This is needed for storage of unmounted specimens and supplies of all kinds. A cupboard 6 feet high $\times$ 6 feet wide $\times$ 16 inches deep, with three doors and three compartments each fitted with shelves that may be set at various distances apart, gives sufficient room for the proper care of a good working stock.

20. Charts.—Excellent charts of plants and animals are available and should be used to supplement the specimens. Select charts large enough to be seen from every seat in the room if they are to be used with large classes. Those with a black background are good. Ask dealers[1] for catalogues of charts rather than for general catalogues.

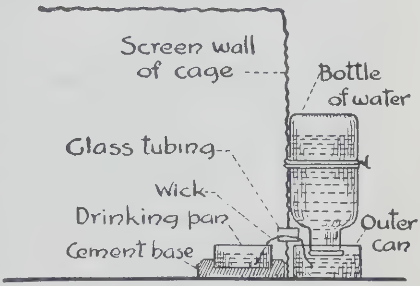


Fig. xv.

Charts soon become worn if not kept rolled up and protected when not in use. Spring rollers are best for this purpose. By mounting your own on window blind rollers, nearly twice as many charts may be procured with a given amount of money; but if you cannot do this, purchase charts ready mounted. The best position for charts in many classrooms is at the side, but this must be determined by trial. If there is a shelf over the blackboard (see Sec. 19), an excellent place to mount the rollers is on the under side of the shelf. The brackets may require to be bent with pliers to work in this inverted position, but several charts may be mounted one behind the other.

21. Cleaning skulls of animals.—The following is a good method of cleaning skulls of rodents or other animals in order to show teeth and other parts: First take off the skin and such muscles as can be removed with a sharp knife. Then boil the skull until the remaining muscles readily separate from the bones. If the water is very salty, it will boil at a higher temperature, and, in case the work is interrupted, the salt will preserve the material. A more rapid solution may be made by adding

[1]Christie School Supply, Limited, Brandon, E. N. Moyer Company, Limited, Winnipeg, and Central Scientific Company of Canada, Limited, Toronto, handle various types of charts.

gold dust or the following solution to the water: hard soap 1 oz., saltpetre 1 oz., strong ammonia 2 oz., soft water 1 gal. These solutions will make the bones whiter, but care must be taken to avoid boiling too long in them, as this causes the skull bones to fall apart, and they must then be stuck or wired together again.

22. Mounting skulls and other small specimens for handling.— Specimens that require much time and patience in preparation have value in proportion, and should be mounted in such a manner as will protect them while being handled. This is particularly true of those that are to be passed around the class.

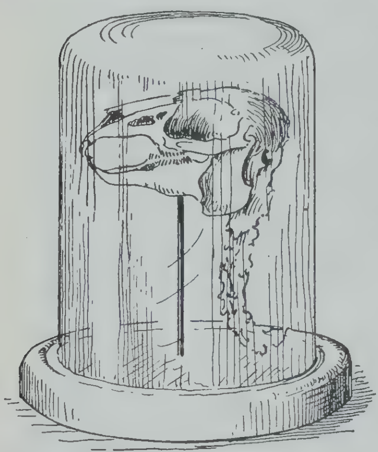


Fig. xvi. Skull of rabbit mounted under a beaker on a wooden base.

Very small skulls, such as those of mice, may be mounted under the dome end of a test-tube cut off for the purpose, or in a short, wide vial.[1] The skull is supported on a cork pushed into the groove behind the roof of the mouth. The lower jaw is held in place with glue. A wire inserted in this cork may have the other end set in the larger cork that fits into the mouth of the test-tube or vial.

Skulls up to the size of that of a rabbit may be mounted in a similar manner under an inverted beaker as shown in Figure xvi. The lower jaw of these larger skulls should be held in place by thread or wires. Very fine copper wire, obtainable on small spools, is good. Holes may be made with a very fine drill such as is used by watchmakers, if it is desired to conceal the wires. The base in this case is a piece of wood or a cake of plaster of Paris. The wooden base may be turned on a lathe with a groove in which the edge of the beaker is sealed with wax or pitch from dry cells or other suitable material (Fig. xvii). A very satisfactory wooden base may be made as indicated in Figure xviii, using only the simple tools that should be in every science room. The specimen is mounted on a wire or a wooden peg set in a square piece of board, and a label is attached showing place and date collected. collector's name, and

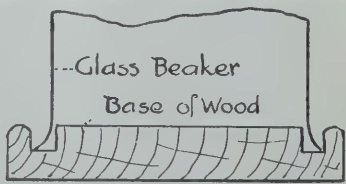


Fig. xvii. Beaker set in groove ready for sealing.

[1]Shell vials are best. They should be ordered in short, broad shapes and fitted with corks.

name of specimen. Then the beaker is placed over it and held down by a piece of cardboard that has been cut to fit over it and to hold it down by the rim. The outer edges of the cardboard are trimmed to fit to the edges of the board, and the cardboard is fastened to the board by gummed paper tape or other adhesive. Tirro tape and surgical adhesive tape are good. A piece of tape should seal the carboard to the glass also to keep out dust. The cardboard and base may be painted black or otherwise finished.

Skulls and foot-bones that are too large for beakers may be mounted in cases made from sheet celluloid as described in Section 15. These should be securely wired. Care must be taken in all cases to see that the bones are very dry before they are enclosed. If any moisture remains, they will mould or decay, and it will be necessary to boil them again to clean them.

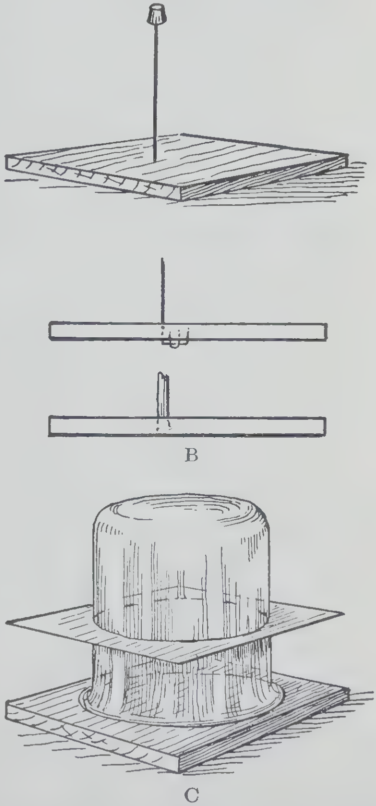


Fig. XVIII. A, Wire with cork that supports skull. B, Method of securing wire and wooden peg. C, Attaching beaker to square base.

23. Use of formalin and methyl hydrate.—Formalin is sold in one-pound bottles and larger containers. Cloudiness or white sediment will disappear when it is mixed with water. This is not an impurity. Formalin that is to be used for preserving specimens should never be placed in a metal vessel or allowed to come in contact with metal spoons, funnels, etc. Sealers used for storing material in formalin should be of the "Victory" pattern or some other kind without metal screw tops if possible. Crocks also are suitable for this purpose. Formalin, since it is a gas dissolved in water, remains strong only if it is kept tightly covered.

Formalin is poisonous if a considerable amount is taken, but is so irritating to the nose and throat that it can hardly be taken by mistake. (Antidote: Give a large amount of water, milk, egg, etc., and cause vomiting.) It is harmless to clothing and skin, but, after a time, it makes the hands "chapped."

Methyl hydrate, or wood alcohol, is an inflammable liquid, and the vapor coming from it out of an open bottle may take fire from a lamp or stove at some distance. It is very poisonous, causing blindness, if not death; but, like formalin, it cannot be mistaken for water on account of its taste and smell.

For preserving ordinary plant material in formalin, use 3 per cent solution (i.e. 3 parts formalin to 97 parts water). For soaked seeds or other material that is likely to ferment and already contains much water, use 5 per cent formalin. For animals the size of a mouse or larger, use 10 per cent solution. The body cavity of the animal should be opened to allow the preservative to enter, or the preservative should be injected into the digestive organs and thicker fleshy parts with a hypodermic needle. Feet of animals may be thus injected with 100 per cent formalin and then quickly dried in a warm place.

Where there is danger of frost, plant or animal material may be preserved in methyl hydrate. Insects keep in much better condition in methyl hydrate or in ethyl alcohol than in other preservatives, and should be so preserved if they are to be used later as class specimens. To avoid freezing, the solution should be about 75 per cent methyl hydrate. If desired, in place of these, the "Rubbing Alcohol" sold in drug stores may be used. Some anti-freeze mixtures are good preservatives.

To mix a 5 per cent solution of formalin in a sealer, mark off 5 per cent, or one-twentieth, of its depth *near the middle* of the jar. Fill the jar with water to the lower mark, then add formalin to bring the surface to the upper mark, and fill the remainder with water. The reason for adding the formalin at the middle of the jar is that the shape is usually irregular at the top and bottom.

If ¼ teaspoonful of borax is added to each quart of formalin solution, the colors of specimens will be better preserved.

24. Building an aquarium.—Suggestions are here given that will apply to the making of a tank of any reasonable size. This project requires a soldering kit, tinsmith's snips, some skill in soldering, and a considerable amount of patience. Before commencing work, make a careful plan allowing in measurements for thickness of glass, cement, and metal. The width should be greater than the depth to give plenty of surface. A good size would be 18 inches long × 12 inches wide × 10 inches high. This would hold nearly 8 gallons of water and would have 1½ square feet of surface.

(1) Bend up the sides of a sheet of fairly heavy galvanized iron or heavy zinc to form a shallow pan (A) for the bottom of the aquarium. (The corners need not overlap.)

(2) Solder the corners, attaching inside each corner a vertical angle-piece (B). (They may be kept square while working by fitting them over the corner of a chalk box slightly rounded off.)

(3) Solder *four* angle pieces (C) to the outside of the bottom of *A*, after trimming the corners along the dotted lines. This forms a groove as at *Cg*. This groove should be $\frac{3}{8}$ inch wide for glass $\frac{1}{8}$ inch thick.

(4) Solder four angle pieces (D) on the outside of the corners of *C* as at *Dx*. Keep these square and even with the pieces *B* by inserting $\frac{3}{8}$-inch pieces of wood between. They are wider and slightly longer than *C*.

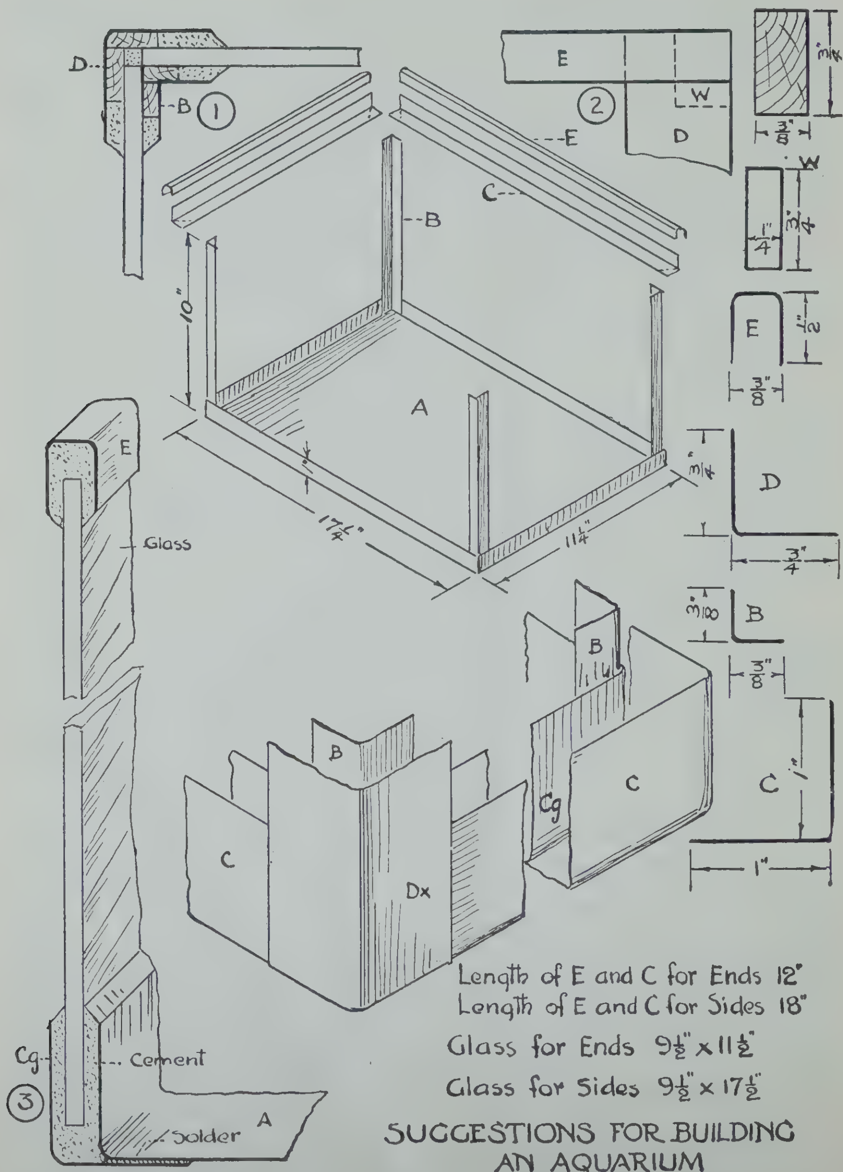
(5) Cut glass to fit in the four sides leaving $\frac{1}{4}$-inch space in the frame round the edges of each piece. The pieces of glass will just meet at the corners as in (1). Protect both sides of each piece except at the margins with paper attached by gummed tape.

(6) Half fill the bottom grooves with aquarium cement obtainable at bird and pet stores (see advertising section of large city telephone directory to be found in branch offices), or with other *waterproof* cement. Press in the glass until it is $\frac{1}{4}$ inch from the bottom of the groove, and $\frac{1}{4}$ inch below the top of the corner pieces. Work in more cement to fill the bottom grooves and spaces between corner pieces, being careful to enclose no air bubbles in the cement in any part.

(7) At the top insert little blocks of wood (W) $\frac{3}{4}$ inch $\times$ $\frac{3}{8}$ inch $\times$ $\frac{1}{16}$ inch between the glass and the outer metal corner pieces. Between the glass and the inner corner piece insert blocks $\frac{3}{4}$ inch $\times$ $\frac{1}{4}$ inch $\times$ $\frac{1}{16}$ inch as shown at (1). These prevent the cement from being squeezed out. They should be dipped in hot melted paraffin before use. Accurately fit two diagonal strips of wood, equal in length, an inch below the top of the aquarium to keep the top square, then bind a string fairly tightly round at this height to keep the corner pieces firmly drawn together.

(8) Four top pieces (E) may now be cut to fit their places and "tinned" with solder $\frac{3}{8}$ inch at each end inside. Fill them only $\frac{1}{4}$ inch deep with cement, keeping the $\frac{3}{8}$ inch at the ends clean, and lay them in place, but do not press heavily. Solder them in place, applying heat only where the wooden blocks are behind the metal (see 1 and 2). Remove the string, fill in the edges of *E* with cement, gently clean off any surplus cement from the glass, and set the aquarium on a board to prevent twisting. Put it away in a warm place for a week, or until the cement is well set. After it is well hardened, protect the frame with waterproof paint or varnish and let it dry. Fill the aquarium with water to test it and clean it. Change the water several times during the first week.

25. Storage of phosphorus.—Phosphorus ignites when exposed to the air and must therefore be stored in water to keep air from it. In places



1
2
3
D
B
E
W
C
A
10"
17¼"
11¼"
Glass
Cg
Cement
Solder
Dx
Length of E and C for Ends 12"
Length of E and C for Sides 18"
Glass for Ends 9½" x 11½"
Glass for Sides 9½" x 17½"
SUGGESTIONS FOR BUILDING
AN AQUARIUM

Fig. xix.

where there is danger of frost the bottle must be so placed that it will not break if the water freezes. A very small amount of phosphorus is sufficient (a piece the size of a pea for each class), and it may be safely stored in water as shown in Figure xx. The bottle is partly buried in a metal dish containing sand. It is placed in such a position that the bottom is *less than half covered* and the water does not reach up to the top of the straight side. Should the bottle break, the phosphorus could burn in the sand without danger. Glycerine is said to be a suitable non-freezing liquid for phosphorus, but results are not yet available.

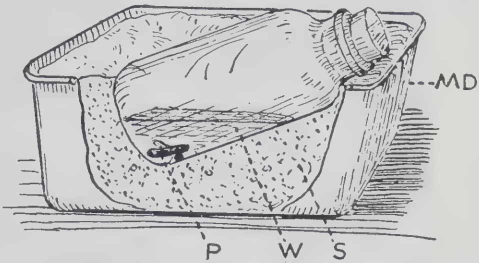


Fig. xx. Method of storing phosphorus. MD, Metal dish. P, Phosphorus. W, Water. S, Sand.

26. Raising meal worms for animal food. — Meal worms, the larvae of beetles, make excellent food for many animals including frogs, toads, fish, mice, squirrels, and birds. Obtain some of these worms from the pantry or from a dealer in bird food and place them in a tight tin box of about 2 gallons capacity together with a mixture of bran, corn-meal, graham flour, and oatmeal. Bran alone will do, but the worms develop more rapidly if given a varied diet. Fill the box to a depth of 4 or 5 inches with this mixture. On top of the mixture place a few shavings or pieces of shingle under which the insects may hide. Cover the box with a piece of fine wire gauze to prevent the insects from escaping. A cloth cover may not be used because these animals can eat their way through it. If the box is put in a dark, warm place, the insects will multiply very rapidly and, after a few weeks, will provide sufficient food for a number of animals. Add more food as it becomes eaten by the worms.

When you wish to obtain some of the worms from the box, spread a handful of the mixture upon a piece of paper and pick up the insects with a pair of forceps.

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